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EDITED BY DOROTHY E. ROSE

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PAPERS IN BOTANY

EXTRACT FROM THE REPORT OF THE SECTION CHAIRMAN

In addition to papers published herewith, the following were presented at the meeting of the Botany Section:

"Mechanics of Growth in the Stem-tip of Seed-plants," by J. T. Buchholz, University of Illinois.

"Supplements to the Undergraduate Courses in Biology," by Sister Mary Ellen O'Hanlon, Rosary College, River Forest.

The following papers were read by title only:

"Life-forms of Illinois Plants," by S. J. Ewer, University of Illinois.

"*Haplosporangium decipiens* Thaxter, and other microfungi from Illinois," and "Antipodals in Zinnia," by B. T. Palm, University of Illinois.

"The Status of our Knowledge of the Illinois Flora," by H. S. Pepoon, Chicago.

"A Mesic Rock-Ravine Area in East Central Illinois," by E. L. Stover, Eastern Illinois State Teachers' College, Charleston.

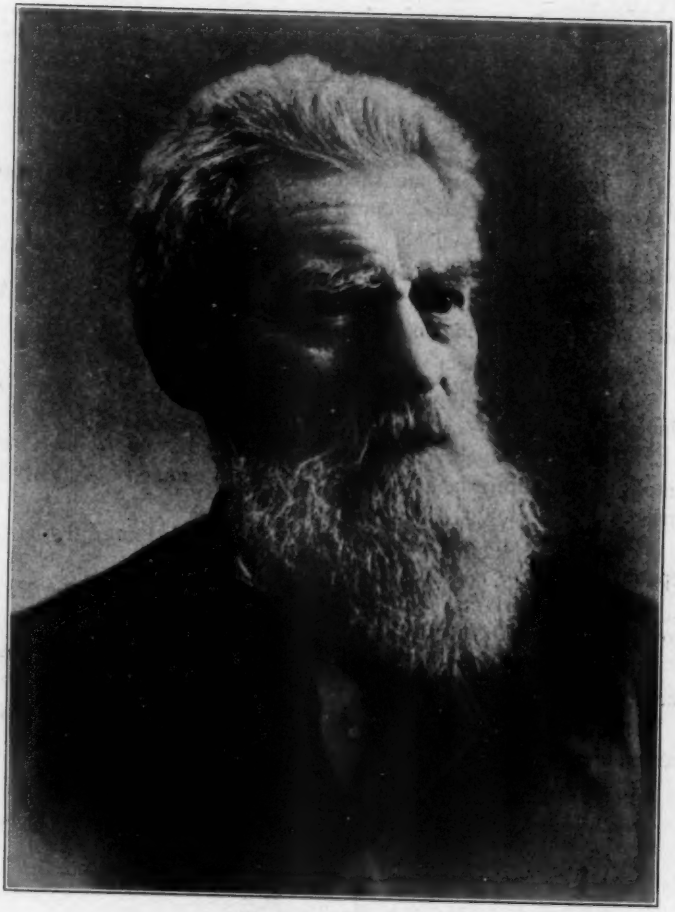
"Plant Succession at Taupaushaw, Nantucket," by Dixie Pelluet, Rockford College.

The average attendance at the section meeting was forty-five; maximum attendance sixty-six.

No chairman was elected for 1931-1932.*

(Signed) A. G. VESTAL, *Chairman.*

*The Council later appointed Dr. Charles A. Shull, Chicago, as chairman for the following year.



FREDERICK BRENDEL

FREDERICK BRENDEL, THE PIONEER BOTANIST OF PEORIA

BY

VIRGINIUS H. CHASE

Peoria, Illinois

Let us look back one hundred eleven years. James Monroe, our fourth president, was then in office and the great Napoleon was still a prisoner on St. Helena.

It was on January 20, 1820, that to the house of Brendel, Mayor of Erlangen, Bavaria, was born a son, soon after to be christened in the Lutheran Church with the name of Frederick.

The Brendels of many generations had lived here, honored and respected, a people of culture and refinement, whose sons began their education with the distinct understanding that there was no stopping-place until they had earned a diploma and college degree at the University of Erlangen.

The Mayor was widely known as the owner of the wagon works of the city, where the great freight wagons were built for transporting the products of German factories to all parts of Europe in the days before steam locomotives.

The boy was sent to common school at the age of six and the next year began what he was pleased to call "a seven-year fight with Latin."

He was also sent to Sunday school, but "the boy is father of the man" and we are interested to find that little Frederick preferred listening to the skylark and the amsel rather than to homilies and slipped away to the woods; but played safe by waylaying a less daring chum, and getting the Golden Text and the gist of the lesson before going home.

The fields and woods were the very breath of life to him and it is little wonder that his playmates nicknamed him "der Wilde," or the wild one. I am sorry I have not the details of those early years, for I feel sure they would be as entertaining as the escapades of the "Madman" of "Tom Brown's School Days."

As a boy he collected plants and frequented the lectures of the venerable Koch, author of *Flora Germanica*, in the summer semester of 1840, and took part in the Saturday excursions under his direction. With good health and alert mind the days quickly passed, and at nine-

teen he entered the university of his native city to come forth with high honors as an M. D., August 21, 1843. From 1846 to 1848 he was assistant physician of the surgical department of the city hospital at Bamberg, but lost the position because of his radical political activity.

When he was thirteen years old an incident occurred which made a deep impression on his mind. There was a secret democratic movement on foot against the monarchy and a group of young men were arrested and some of them executed, among them one who had been staying at the house of the mayor. To the boy they were martyrs and heroes, suffering for a great cause.

Then came the political uprising of 1848, and young Brendel, whose feelings were too strong to be hidden, was brought before the court and accused of editing a seditious paper. "If I *were* guilty I would not answer "yes," for the law does not require me to convict myself; it is your privilege to prove it to me if you can," said the young doctor. He was reprimanded and refused permission to practice medicine unless he chose to show himself loyal to the monarchy and was given to understand that the country would be better off without people of his belief. So on March 2, 1850, he embarked for New York, as Engelmann, Lindheimer, and many others of Germany's finest young men had already done.

The voyage of forty-six days on the *Elizabeth Dennison*, an American sailing vessel under Captain Spencer, brought him to New York where he was met by Eberhard Faber, the pencil manufacturer.

The first book he bought a few days after landing was a copy of the second edition of Beck's "Botany of the Northern States" and his first plants, collected north of Hoboken, were *Cornus canadensis* and *Saxifraga virginiensis.*

After a brief stay here he journeyed westward, botanizing at Albany, Niagara Falls, Sandusky, Cincinnati, and St. Clair County, Illinois, collecting about five hundred species.

During the next year he collected nearly all the vascular species that occur in St. Clair County and St. Louis, and began an acquaintance with Dr. Engelmann, which continued up to the time of Dr. Engelmann's death.

Two years later in company with Dr. Feinse, he moved to Peoria, arriving there February 11, 1852. Dr. Brendel made his home in what was then a very suitable part of the little city, on Water street, with his office in the same building. Later he moved his office to Mathie's Drug Store at the corner of Bridge and Water streets.

It was the custom of that time to write code prescriptions to be filled by the apothecary. Here he led the life of a typical country

doctor in the days before telephones, when half the country roads were only trails and people came post haste on horseback and the doctor held himself ready to dash away at any minute—day or night, rain or shine.

He stood at the head of his profession both as a physician and surgeon, but it was in a day when home-made herb teas and drug store patent medicines were kept in every home to save expense, so I have no doubt the good doctor had many an hour of undisturbed study.

On Sundays with his large tin vasculum he was away to the hills or bogs collecting plants and studying the mystery of life in all its forms.

He was familiar with seven languages and spent a large part of his income on scientific books from all parts of the world. His library contained more than two thousand volumes, ranging from the large folio of L'Heritier on *Cornus* printed in 1788, or Persoon's little *Synopsis Plantarum,* no larger than a prayer book, printed in double columns in 1805, to the later-day reprints of short articles sent him with the autographed compliments of the authors. These latter were carefully bound by his own hands.

In 1855 he began recording the daily temperature, the rainfall, and other meteorological items. This record was faithfully kept for fifty years. Fuller, of the local weather bureau, records that the doctor while ill and lying day after day apparently unconscious would rouse regularly near the observation hour and direct the nurses to read the thermometers.

He was elected vice-president of the Illinois State Natural History Society at Bloomington, June 30, 1858.

In 1860 he collected in the southern counties—Jackson, Union, Pulaski, and Alexander—specimens of such woods as are not found further north, forming a nearly complete collection of Illinois woods which was exhibited at the state fair in Jacksonville the same year.

His general herbarium contained about eight thousand species, many of them represented by specimens from several localities, and in addition to this he had a separate collection of Illinois plants containing the species mentioned in "Flora Peoriana."

It was largely by his efforts that the Peoria Scientific Association was organized, April 17, 1875, with the doctor as vice-president. In ten years, Dr. J. T. Stewart, his able companion, records, one hundred sixty-seven papers had been read, the museum contained more than ten thousand specimens, and the library one hundred and fifty volumes. During this tenth year no less than seven thousand seven hundred visitors had inspected the collections.

The Pentstemon Society, a happy group that met in the woods to enjoy life in the springtime, the German library, and the German school were all promoted by the doctor and his close associates of the Scientific Association.

One day in early autumn he set out alone on foot among the bogs of the Illinois river bottom to gather seed of *Lobelia cardinalis* for friends in the Fatherland. In the tall timber, twilight comes early, and becoming lost he floundered among the hummocks until nearly exhausted. At last he spied a light in a farm house at the foot of the bluffs and finally long after dark managed to reach it.

His family after a sleepless night were overjoyed to see a farmer's wagon come up the street bringing their beloved father to them once more. His first words were, "Did you remember to read the thermometer?"

Another incident which has been related to me tells of his being called away from an interesting specimen to attend a country patient. The doctor walked in the front door and on out the back, got into his buggy and started for home. If I laughed when I heard this it was not at the dear old man but rather at the consternation of the patient's household.

More and more as he grew older the importance of the eternal truths of science and the insignificance of mere temporal matters grew upon him.

In 1887 the results of his years of study of the local plant life were published as "Flora Peoriana," recording the presence of eight hundred thirty-five species and varieties of native vascular plants, as well as mentioning all introduced species and listing the mosses and hepatics. Many of the species are now extinct, and none of us have been able to add any considerable number to the list. Of the few unrecorded ones I have found I would not wish to boast; it would please me better to discover a later record in some unexpected place or an herbarium specimen labeled in his handwriting in some old collection.

"Flora Peoriana" is no mere checklist, but beginning with the climate, topography, and geology, the author discusses the flora of the prairie, the woodland, and the swamp; considers the introduced plants and the cultivated species. He then analyzes and compares order by order our flora with that of other localities and shows the distribution of these same species in other states and finally lists all Illinois species not yet found within the Peoria region.

His herbarium is now at the State University. His books are scattered; some the family still treasure, I myself have a few, some were loaned and never returned.

I wish the local Academy might feel it their duty to raise funds to acquire all that may still be available of this valuable library. I would gladly donate the half dozen volumes which I have.

Of his collections of other branches of Natural History—insects, reptiles, and mollusca—all we can say is that they are gone.

His immense file of correspondence with letters from practically every American scientist of the nineteenth century has been burned.

As I have gone about searching for items for this paper, the remark heard most often is, "He was a great man—greater than we realized; he was not properly appreciated."

He modestly held to the belief that the making of new species should be left to the professional scientist and so far as I have been able to find he never once published a new species or had one named in his honor.

He was a physician and surgeon of note, an all-around naturalist of the first rank, a nature guide before the National Parks were organized, a meteorologist before the Government began its records, and as an agrostologist of the U. S. Department of Agriculture recently expressed it, he was an ecologist before that word was invented.

That he was a poet as well we cannot doubt as we read his description of the woodland:—(Vol. III Trans. Ill. State Agr. Soc.)

"It is a singular charm, to roam in a mighty forest, now below the green dome of transparent foliage, the lofty home of a melodious chorus, diffusing a magic light over the flower covered ground; now below the darker shelter of a thick, leafy roof, where the mossy stone checks the murmuring rivulet, or the woodpecker's monotonous thump only interrupts the solemn silence.

"Upward winds our path; we proceed to the platform of a steep rock. How delightful a scene opens to our view below! The rocky walls rise above an ocean of manifold shaped foliage, resplendent in fall-time with a variety of brilliant different colors and shades; a broad stream winds through the valley, reflecting on its silvery sheet the forms of the bordering willows or the houses of a peaceful village, or the smoking factories of a noisy city, on the background of which stretches the wide prairie, crossed by roads and checkered with farms and small groves.

"The horizon bounds a line of wooded bluffs. Everywhere a variety of points for the eye to rest on.

"A treeless plain fatigues the eye; a wilderness of naked rocks arouses gloomy sentiments; but the woods embellish the landscape as the curling hair does the child's blooming face.

"To rob a country of this ornament, manifests a want of good taste. To destroy entire forests of useful trees proves an abundance of damnable heedlessness, which does not care about the future, and has been repented in many cases when too late."

The doctor married Miss Elizabeth Miller in 1861 and of their twelve children one son and six daughters were living at the time of his death August 10, 1912.

At his own request his body was cremated.

From the doctor's pen we have the following:

In Gerhards, "Illinois as it is," 1857, 3 maps which show geological formations, population, and distribution of forests and prairies; also a chapter on "Climate, Soil, Plants, and Animals." In the Transactions of Illinois State Agricultural Society, Volume II, 1856-57, "Historical Researches upon Cultivated Grain Fruits in the State of Illinois," and also in Volume II, "An abstract of Meteorological Observations for the year December 1, 1855 to November 30, 1856." In Volume III (1857-1858) of the same "Transactions" are, "Additions to Lapham's list of the Illinois Flora—79 species," followed by a list of 27 species of mosses found in the vicinity of Peoria, and also "Trees and Shrubs of Illinois," and "The Oaks of Illinois," with 10 plates. Volume IV contains "The Trees and Shrubs of Illinois" (continued), with 10 plates of which the doctor writes, "Disgusted by the bad execution of very good drawings by a probably cheap artist, I did not continue any more."

The Transactions of Illinois State Natural History Society includes a paper on "The peculiar growth of the Water Lily *Nelumbo lutea,*" read before the society in June, 1860, and illustrated with one plate.

In the American Naturalist, May-June, 1870, is the article, "Nomenclature and Classification of American Oaks," an extract from which was published in the Entomologist and Botanist, St. Louis, July and August, 1870.

"The Tree in Winter," illustrated with four plates, was published in Bulletin 1 (1876) of the Natural History Survey of Illinois, and "Historical Sketches of the Science of Botany in North America from 1635 to 1858," appeared in the American Naturalist in December, 1879.

The Bulletin of the Scientific Association of Peoria in 1887 contained "The Climate of Peoria," read September 24, 1886, and "Immigration of Animals and Plants," read September, 1886.

In the Secretary's report for the year ending May 1, 1886, it is recorded that Brendel presented two other papers on "Grasshoppers" and "Early French Settlements in the Western States," which were

probably never printed. "De Floren Gebiete Nordamerikas," was published in the Zeitschrift für die gesammten Naturwissenschaften, Vol. 41 (1873).

"Flora Peoriana" was originally written for "Flora," a German periodical of Ratisbone, but the editor although willing to publish refused to include the meteorological part which the doctor considered essential, so the manuscript went on to Budapest where it was published in German in 1882. Engelmann took his friend to task for not publishing it in English, so Doctor Brendel rewrote it and had it printed by J. W. Franks and Sons in Peoria in 1887.

To Doctor Brendels' eldest daughter and her husband, Mr. Emil Wagishauser, with whom the doctor made his home in his declining years, the writer is indebted for most of the facts recorded here.

STRATEGIC HABITATS AND COMMUNITIES IN ILLINOIS

BY

A. G. VESTAL,

University of Illinois, Urbana

INTRODUCTION

This paper is intended to be a roll-call of areas in Illinois which are of more than ordinary interest to biologists, either because of local peculiarities of habitat or history which favor the presence of less common plants and animals, or because of particularly good preservation of original conditions and the original communities. Its primary purpose is to appeal to those who may know of similar localities to bring them to the attention of others, so that all of us may know of their existence and visit them as we can, for scientific study, for instituting measures which may lead to their continued preservation, for field study by classes of students, and for the enjoyment which rewards the biologist who can appreciate the significance as well as the beauty of the native vegetation in its original setting. It is suggested that such localities be reported to the Academy's Committee on Ecological Survey, or to the Committee of the Ecological Society of America which is working to preserve such areas of natural conditions. The chairman of this committee is Dr. V. E. Shelford, Vivarium Building, Champaign, Illinois. It happens that one of the present activities of this committee is the selection of notable areas which are so located that each can be visited by classes from two or more colleges or universities. It is entirely possible that correlated efforts of several of these institutions may result in long-term lease or in purchase of selected tracts of land for study purposes.

Aquatic habitats and communities are not included in this list. The land areas of original conditions included prairie, almost entirely confined to flat or rolling uplands, forest of a number of types, chiefly developed on moraines or in stream valleys and in places spreading extensively from these over the general surface. Inasmuch as glacial till with silt-loam soil and heavier subsoil covers most of the area, it follows that the non-glaciated areas, and coarse soils (sand or gravel) or rock outcrops, provide the chief departures from the relatively uniform substratum which prevails over any extensive part of Illinois.

Furthermore, areas of more rugged topography are of interest because they are so much less extensive and because they provide greater diversification of habitats and of vegetation.

In the list which follows, *types of habitat* or *community* are printed in italics. Representative localities are mentioned under each type. It is particularly hoped that readers of this list will supply information as to other examples of such habitats and communities, to the author, to Dr. Shelford, or to any member of the Academy's Committee on Ecological Survey.

Habitats Notable Because of Topography or Substratum

Ravines with rock outcrop. These include the canyons of Starved Rock (Sauer, Cady, and Cowles, 1918; Thone, 1922), and smaller canyons along lower Fox River; Apple River and other canyons in northwest Illinois (Pepoon, 1909), and local rock canyons of tributaries of Rock River (DeForest, 1922); Rock canyon on Rock Creek on the north side of Kankakee River; Rocky Branch, Big Creek, northern Clark County (Stover, 1930); many steep ravines in the bluffs of the Mississippi, with rock outcrops at the base of bluffs. Residual soil overlying rock is also of interest. It is very local in occurrence and is found near rock outcrops in the larger valleys.

Gravelly knolls and other coarse-soil areas. Prickly-pear cactus has been reported from a gravelly knoll north of Laclede in southeastern Fayette County and in gravel of the lower Wabash valley. Other xeric plants are presumably there also. The prickly pear is likely to serve as an indicator of coarse soil; the places in which it occurs in southern Illinois should be made known.

Sand areas. Recent invasion of black oak occurs on most of the sand ridges in the Kankakee area, yet the sand-prairie flora remains, with patches of sand-prairie vegetation. The more extensive areas of sand-prairie near Illinois River, with blowouts and dunes, are fortunately not easily amenable to agriculture and therefore of low value, so that their purchase should be feasible. The Devil's Neck, north of Topeka in Mason County, should be acquired, together with nearby areas covered with scrub oak. Two sand areas in the Kankakee valley are especially notable, one west of Kankakee, the other east of St. Anne. The sand areas of the Wabash valley, although small, scattered, and mostly used for cultivation of melons, may still include a few places with native vegetation. Allison Prairie, noted by Eaton (1931:150) is one such area to examine.

Mixed sand-and-loess deposits. These are found at the leeward edge of valleys of the Illinois and Mississippi rivers, at the base of bluffs, and even upon bluff-tops. They exhibit a type of prairie intermediate between sand-prairie and that of the finer soils.

Prairie in the broad valleys of the larger rivers. Remnants of native prairie vegetation are known to occur in the Mississippi valley of northern Illinois, they are less well represented in the Illinois River valley, and have recently been observed in the lower Wabash valley.

Prairie sloughs. Once the prairie sloughs covered a large proportion of the treeless areas, but now they are mostly drained and farmed. Some of the few which are still in the original condition should be made known and preserved.

Bogs of several types. Former river-beds filled in with deep peat occur near Fulton in Whiteside County, and near Manito in Mason County; a few bogs scattered over the prairie areas, and the numerous bogs of northeastern Illinois (Waterman, 1922) offer possibilities. Gates' account of the Beach area (1912) includes descriptions of the bogs and marshy habitats, and he has also called attention to a bog near Matanzas on Illinois River (1911).

The higher and more rugged moraines, as in northeastern Illinois, and parts of the Shelbyville moraine, are likewise of interest, together with the scattered hills of the Old-Morainal Border extending southwestward from the Shelbyville area. Fink has given a brief description (1906) of eskers in Kane County.

Limestone areas with sink-hole topography, which occur southeast of St. Louis, may show few peculiarities of either flora or vegetation, yet they should be investigated, and perhaps efforts should be made to establish one or two preserves of this type.

Non-glaciated areas of the Ozark Hills will certainly be well represented in the State Parks and State and National Forests established already and in the future. The lower hills which interrupt the floodplain south of the Ozarks are less well known. Northwestern Illinois is likely to be represented before long in the State Park system.

Areas Notable Because of Vegetation

Forest islands in prairie. These isolated groves are of two types. The first originates from wind-blown or bird-carried seeds of trees; elm is usually the first tree to be established, hackberry is likely to be an early second. Walnut and hickory, perhaps planted by Indians,

also form a component of these forest islands. Oaks (except shingle oak and pin oak) are rarely present. Linn Grove (Champaign County) described by Gleason (1913) and Round Grove (north of Casey in Clark County; Vestal 1920:243) may serve as examples. The second type of grove, with the oaks present in normal abundance, represents a relict area once part of a larger forest tract, the connection since having been destroyed, probably in all cases by prairie fires. Bur Oak Grove (eastern Champaign County, Gleason, 1912) and probably Charter Grove in DeKalb County, represent this type. The several rather large forest areas of McLean County, now isolated from one another, may once have been connected. They occur on moraines, and whereas much more of the morainal area may once have been wooded, the present forests are chiefly on the more rugged parts of the moraines where the larger streams intersect them. Other small groves, mostly of the first type, are mentioned by Gleason (1913:177) in DeWitt, Macon, Moultrie, Piatt, and Shelby counties. The writer has studied them in Cumberland, Coles, and Douglas counties. There must be others whose existence and character have not yet attracted notice.

Prairie islands in forest. Some of these are merely pinched-off salients of prairie which have become surrounded by the invading upland forest as an incident to its irregular spread. Others, mostly quite small, owe their preservation to some xeric exposure or to a locally coarse or exceptionally well-drained substratum. The larger islands of the first type, as represented in western and southern Illinois, will be particularly helpful in determining the original character of prairie in those parts of the State. Local prairie inclusions of the second type have been noted in the forest belt of the Embarrass River and other parts of eastern Illinois (Vestal, 1919a; see also Shimek, 1910, and Moseley, 1928).

Recent invasion of prairie by forest. In northwestern Indiana, bur-oak groves adjoining prairie have recently been shown, from their slight modification of dark soils, to have succeeded prairie—probably within the last hundred years. Similar bur-oak forests are likely to be found in northeastern Illinois and it may well be that many of the pure stands of bur oak on moraines of this area are likewise very recent. Black-oak dunes of the Kankakee and Winnebago areas are not only recent, but the invading process is still active, and can readily be seen and studied. Similar forest spread in the Illinois River sand is particularly rapid, with blackjack oak as well as black oak.

The projecting ends or salients of uplands, as found between the ravines at the borders of the larger stream valleys, are favorite areas

for invasion of prairie by upland forest. Elm, hackberry, shingle oak, and honey locust are among the invaders wherever drainage is not good. The white oak is notably absent from such areas. The effect of such invasion of upland salients is to rectify and shorten the boundary between forest and prairie (Vestal, 1920:236). It is well shown on the east side of Embarrass River in Cumberland County.

Recent invasion of forest land by prairie. Where railroads cross forest belts of stream valleys, the right-of-way has been invaded in many places by prairie. Examples have been seen near Charleston (Embarrass River forest belt, Vestal, 1919b); near Mahomet (Sangamon River); at various places in Shelby, Fayette, and Montgomery counties; and as far east as Crawfordsville, Indiana. The best of these places should be preserved by an arrangement with the railroads. Some of them show interesting admixtures of forest herbs with prairie plants. Shimek (1913) has described succession to prairie along a broad roadway through an Iowa forest.

No examples of cutover forest lands or of originally forested strip-mine areas which have been revegetated by prairie, have ever been noted in Illinois but the discovery of such a condition is by no means impossible. A few places have been seen in which prairie bunch-grasses have taken possession of the sites of abandoned farm-houses. Prairie plants are found along with the weeds which come up on strip-mine ridges. Usually the pioneer herbs are replaced by trees after a few years, but at Fairmount quarry, in an extensive prairie upland in Vermilion County, strip-mining for limestone has left ridges on which no trees are establishing themselves. Probably blue-grass will in time dominate. The partially flooded bottom of this large quarry is of interest chiefly because of its bird and other animal life. Several strip-mine areas and quarries offer possibilities as nature preserves.

The above survey of the less usual habitats and communities does not attempt to list known stations of the more nearly typical upland prairie, nor the common types of forest of upland, ravine-slopes, and bottomlands in various parts of Illinois. The appeal for information as to localities, however, does cover these more familiar communities, and it is hoped that readers will send to the author the descriptions of all notable areas, together with fairly explicit statements of location, and directions for reaching the stations. It is hoped that the Committee on Ecological Survey will thus be enabled to publish a report which will form a comprehensive Naturalists' Guide to Illinois.

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CONSERVATION OF ILLINOIS AREAS OF BOTANICAL VALUE

BY

HENRY C. COWLES

University of Chicago, Chicago

INTRODUCTION

In discussing areas of botanical value I shall consider two points of view: First, that of the preservation of rare and interesting species of plants, and second, that of the preservation of areas of ecological interest. It happens, fortunately, that many of the areas of ecological interest and many of the areas that have rare species in them are also places of scenic value and therefore are likely to be recommended for preservation by all who are interested in the conservation of natural scenery for the sake of its beauty or for historical interest. For example, Starved Rock State Park, our first and largest State park, was established largely for its scenic value and its historical interest, and at the same time this area harbors many of the most interesting plants of Illinois and many of our most interesting ecological types. The same may be said of many another of our areas that are already State parks or have been recommended for such. Not only are our State parks likely to be places of interest botanically, but also our State forests. In this connection may be noted the proposition now before us of having a large national forest in Illinois. If this is organized and developed it will doubtless harbor many rare and interesting plants and many important ecological areas. In similar fashion, our county forest preserves, like those of Cook County, which include almost all the wild land still left in the county, are likely to have many species and areas of interest. In addition there may be noted the possibility of such city preserves as Trout Park at Elgin, which contains the finest colony in the State of arbor vitae *(Thuja occidentalis)*.

STATE PARKS

First I shall mention the State parks that are already organized and some of their interesting botanical features. In Starved Rock State Park we have perhaps Illinois' southernmost station of the white pine, the arbor vitae, yew, and Canada blueberry, and doubtless some

others. It is also interesting in that it contains fine examples of canyons, rock bluffs, and floodplains and offers most interesting ecological studies.

Giant City Park at Makanda, with its canyons and rock cliffs, is also interesting for its ecological types, being one of the finest places in the State for the study of sandstone vegetation.

The White Pine State Park in Ogle County, which contains our finest stand of white pine *(Pinus strobus)*, was brought into being mainly for the preservation of this beautiful tree in its fine setting, and is a good example of the conservation of an area in which botanical value is the primary feature. This park also contains other interesting plants, such as the Sullivantia and a very fine display of yew *(Taxus canadensis)*.

At the Mississippi Palisade Park near Savanna are many interesting plants and ecological types. There is a very fine display there of some of the orchids which are at the present moment in some danger of destruction due to the introduction of sheep into the park—a procedure that cannot be too highly condemned. The State forest in the southern part of Illinois includes a fine display of bald cypress in Horseshoe Lake, where one of the most interesting ecological and taxonomic types of the lower Mississippi is now conserved.

The Cook County Forest Preserve has interesting floodplains which give us all aspects of floodplain successions. Also certain rare trees and other plants are found in the realms of the Cook County preserves. There, for example, is an isolated colony of the buckeye, found nowhere else in the northern part of the State, so far as I know. The cork elm and ginseng, both rather rare plants in northern Illinois, are found in the Cook County preserves.

Areas Worthy of Conservation

Certain additional areas should be included in the conservation scheme. In Apple River Canyon of Jo Daviess County we have ecological limestone types and also many rare species. Perhaps the most interesting plant of the canyon is the arctic primrose, *Primula mistassinica*, which is unknown elsewhere in Illinois and which has been described by Dr. Pepoon in a previous meeting of the Academy. White pines are found in this canyon and also the rare Zygadenus. There has been some talk of preserving all this area as a State park on account of its scenic and historic value; the plant value alone would be enough to justify its conservation. All interests, therefore, should combine in urging the preservation of this interesting area.

A second area of great interest is the Rock River area between Oregon and Dixon. This is very close to the Ogle County pine woods. Its conservation would insure the permanence of a most interesting flora and also striking scenic features, such as Castle Rock and the Devil's Backbone. This rock is of the same formation as that of Starved Rock and has many of the same plants, such as the white pine and Canada blueberry. It also contains the southernmost Illinois station, so far as known to me, of the yellow birch and white birch. It happens, oddly enough, that the southernmost station of these two trees is on the very same rock, on the south side of the river at Grand Detour.

A third area of great interest is Rock Canyon on Kankakee River near Kankakee. This is a most picturesque limestone canyon and contains a striking colony of *Sedum ternatum*. This colony, so far as I know, is isolated and considerably detached from other colonies of the species farther south.

A fourth area is that of the Waukegan Flats in Lake County, containing the last remnant of the Lake Michigan dune flora within our State. Many of the typical plants of Indiana and other dunes are plentiful here, notably the creeping juniper, the bearberry, and many other plants rarely found elsewhere in the State. There is a very interesting station here of the western painted cup *(Castilleja sessiliflora)*. Both ecologically and taxonomically this area is very rich and should by all means be preserved. It would be a great pity if the State should fail to own the only bit of natural lake shore land within its boundaries.

A fifth area of extraordinary interest is what is known as the Wolf Lake area of Union County in southern Illinois. Here is the only large stand of southern yellow pine, *Pinus echinata*. We have already preserved the only large area of white pine and it certainly would be well worth while to preserve the only large area of the southern yellow pine. By preserving this area we should also hold for all time the only known station in our State of the flame azalea, *Rhododendron nudiflorum*.

The areas cited above are representative of types of things that should be saved for future generations. In these areas would be included most of the important ecological types in our State and many of the rare and interesting species. There are many other areas that should be presented in a complete and all-embracing paper, which this does not pretend to be. Doubtless in Dr. Pepoon's forthcoming survey of the state, many new plants and areas may be added to my short list of those desirable for preservation.

Two types of areas not spoken of above should be mentioned. There is nothing more typical of Illinois than the prairie, but it presents the type most difficult to preserve. Most of the prairie areas have been destroyed by agriculture and cities. Some of the finest original prairies in our state are now within the city limits of Chicago. There are small areas that might be preserved in and near Cook County if public interest could be sufficiently stirred up. Very few people, however, are interested in prairie preservation, inasmuch as the prairie has no features of striking scenic value, although there is nothing much more beautiful than a prairie in full bloom.

One of the most interesting ecological types in the state is presented by the peat bogs or tamarack swamps. Tamarack swamps are found only in Lake and McHenry counties and are very few in number but several are still in a good state of preservation, and one or more of them might be taken over by the State. One of the chief difficulties here, however, is the small area involved and the fact that these areas are of small interest to the average citizen who is not botanically inclined. It would be a pity, nevertheless, to have all of these bogs destroyed, just as it would be a pity to have all the prairies destroyed. It might be that some society, such as the Friends of our Native Landscape or the Wild Flower Preservation Society, could be induced to finance the preservation of such areas as prairies and tamarack swamps, whose conservation cannot be too strongly urged.

I have the hope that this paper may stimulate, in some small degree, an interest in the preservation of botanical areas, whether scenic or not, and that no opportunity will be lost to interest people in such conservation.

THE RELATIONSHIP BETWEEN SOIL AND NATIVE VEGETATION IN ILLINOIS[1]

BY

E. A. NORTON AND R. S. SMITH[2]

Agricultural Experiment Station, University of Illinois, Urbana

A reciprocal relationship appears to exist between soil and vegetation, in that the soil environment strongly influences the character of plant growth and the character of the plant growth strongly influences the character of the soil.

The factors which determine whether a grass or a forest vegetation will prevail are climatic environment and soil environment. Illinois offers an excellent opportunity to study the problems of plant distribution. We have a climatic environment throughout the State suitable for a timber vegetation, but a grass vegetation predominates over a considerable portion of the area. It therefore seems that we must look to the soil environment for an explanation of this peculiar situation.

The soils of Illinois have been derived from glacial drift, wind-blown loess, and alluvium. Not all the surficial deposits covering the area of the State are of the same age, however, for the evidence indicates a relatively rapid accumulation of several formations, each of which is separated by an interval of weathering.[3] The age of parent materials in Illinois soils is very important in discussing inter-relationships, because inherited parent-material characteristics have not been dominated by environmental forces in most areas. The environmental factors which govern the conditions under which soil development takes place are climate, drainage, slope of the land surface, and organic activity, both vegetal and animal. The climatic environment of the State is that of a humid temperate zone, and although variable from south to north, is fairly uniform. Drainage conditions vary from nearly perfect to an almost entire absence of water movement. Slope of the land surface varies from nearly level-lying to steep slopes on which erosion is very active. It is not the purpose of this paper to discuss the action of the soil-forming processes, but it should be pointed out that the nature of these processes and, hence, the nature of their

[1] Contribution from the Agronomy Department, Illinois Agricultural Experiment Station. Published with the approval of the Director.

[2] Assistant Chief and Chief in Soil Survey, respectively.

[3] Leighton, M. M., and MacClintock, P. Weathered zones of the drift sheets of Illinois, Jour. Geol. Vol. 38, pp. 28-53, 1930.

product, the soil, is dependent upon soil environment and, further, that the character of the vegetation is likewise determined by soil environment.

It is generally agreed among pedologists that the prairie soils of Illinois are not a response to climatic environment; consequently, our dark-colored soils cannot be considered as climatic soil types, as are the famous Black Earths of Russia, South America, and of the Dakotas, Nebraska, Kansas, Oklahoma, and Texas.

The prairies of Illinois must be explained on some other basis and that basis appears to be complex, rather than simple, involving age, source of tree seeds, and drainage.

The ecological factors which are generally considered to control vegetation in a particular area are climatic, biotic, and edaphic. As stated above, the climate of Illinois varies somewhat from north to south, but the variation is not of sufficient magnitude to be a factor in determining the distribution of grass and timber. The work of Mosher[4] and of Miller, Chapman, and Telford[5] indicates that plant species are not confined locally because of climate, but are found generally distributed over a relatively large area. This evidence supports the suggestion that the existing climate is not an important factor in the present plant distribution over the State as a whole. Transeau's[6] suggestion that the ratio of rainfall to evaporation from a free water surface determines the type of plant association to be found is not directly applicable to Illinois, because all other land areas on the earth having a ratio of rainfall to evaporation in a range between 60 to 80 per cent, such as exists in this State, have general vegetational conditions unlike those in Illinois. The partial elimination of both the climatic and biotic factors leaves the edaphic factor as the most important consideration in the distribution of plant species in Illinois. Topography is one of the edaphic factors, but because of the recognized correlation between topography and soil type in Illinois,[7] we may conclude that soil is the primary factor governing native vegetation in the State.

In discussing geographical distribution and ecological relations of plant societies, Transeau[8] used the term, "center of distribution." He did not imply by this that plants necessarily spread from certain centers but that existing climatic conditions in any given locality were

[4] Mosher, E., The Grasses of Illinois, Illinois Agr. Exp. Sta. Bull. 205, 1918.
[5] Miller, R. B., Chapman, H. H., Telford, C. J. First, Second, and Third Rpts. on a Forest Survey in Illinois, Illinois Nat. Hist. Surv. Bulls. 14, 15, and 16.
[6] Transeau, E. N., Forest Centers of Eastern America, Amer. Nat. Vol. 39, pp. 875-889, 1905.
[7] Norton, E. A., and Smith, R. S., The Influence of Topography on Soil Profile Character, Jour. Amer. Soc. Agron. Vol. 22, pp. 251-262, 1930.
[8] Transeau, E. N., The Geographical Distribution and Ecological Relations of the Bog Plant Societies in North America, Bot. Gaz. vol. 36, pp. 401-420, 1903.

most favorable for a particular type of vegetation to make optimum growth there. Borrowing Transeau's idea, but changing it to include edaphic factors chiefly, we can use the term, "environmental center," to express the relationship which exists between the soil and native vegetation in Illinois. That is, the vegetation present is in response to the environment produced by the soil, which is itself partially the product of the operation of the climatic factor.

This statement suggests an answer to the frequently discussed question, "What is the origin of the prairie?" Many of the articles written on this subject must be considered fiction, particularly those accounts of most pioneers and early historians. Shimek's[9] suggestion that the treeless areas were due to fires, Jones'[10] statement that the prairies were due to rapid drainage of post-glacial waters, and Miller's[11] idea that animals reclaimed the prairies from the forest may be partially correct, for all these factors probably had some influence, but certainly only locally. Sampson[12] sums up the situation as follows, "Climatic factors are important in determining the general boundaries of distribution of the prairie, while edaphic factors are important in determining the origin and character of the prairie associations within the boundaries. The edaphic factors become more and more important toward the edges of the prairie, as in eastern Illinois. When a prairie association is once established, biotic factors and prairie fires are important in checking invasion by forest vegetation." Sampson's conclusion that climatic factors are important in determining the general boundaries of the prairies could not be accepted without qualification.

Expressed in terms of "environmental center," *Andropogon furcatus* and associated grasses were the predominating vegetation over much of Illinois at the time it was settled, because the features of the soil more nearly met the optimum requirements of these plants than those of any other species. Forests had not invaded the area, due chiefly to soil immaturity and lack of subsurface drainage or to the existence of a continued high water table.

The following evidence supports this viewpoint. (a) The geologically older portions of the State have been more heavily timbered than the younger portions. (b) Forests occurred on nearly every well-drained area of the State, irrespective of whether it had always been well drained or became well drained due to the extension of drainage into a previously nearly level-lying, poorly drained region. (c) Prior

[9] Shimek, B., The Prairies, Lab. Nat. Hist., State Univ. of Iowa, Bull. No. 1, 1911.
[10] Jones, P. M., Origin of the prairies of the middle west, Sci. Vol. LXVI, No. 1710. Oct., 1927.
[11] Miller, A. M., Origin of the Prairie, Sci., Vol. LXVI, No. 1722. Dec., 1927.
[12] Sampson, H. C., An Ecological Study of the Prairie Vegetation in Illinois, Illinois State Nat. Hist. Surv. Bull. 13, pp. 523-577.

to habitation, the drainage on most of the non-forested areas of the State was poor, resulting in water remaining on the land well into summer. Areas which have not been artifically drained still present this condition during wet seasons. (d) The characteristics of the soil in the transition area between the forest and the prairie exhibit a gradual change or evolution, suggesting that a change of soil environment allows the forest to encroach upon the prairie. (e) Trees grow remarkably well in the prairie when planted by man after artificial drainage is established.

The conditions in Fulton County illustrate the dominance of the drainage factor in determining the environment of plant associations in Illinois. All of the rolling, better-drained upland in the southern half of the county has been covered by timber, whereas, narrow, nearly level, originally poorly-drained necks of prairie have persisted between large timbered tracts, and in several places extend down to within less than a mile of the Illinois River bottom. It is true that some of the nearly level-lying areas in this region have been timbered, but these are small and are thought to be the result of improved drainage through headwater erosion. Furthermore, when a small area becomes entirely surrounded by forest, the timber will gradually establish itself in the area, despite somewhat unfavorable environmental conditions.

PLANT SUCCESSION ON LEVEES IN THE ILLINOIS RIVER VALLEY

BY

LEWIS M. TURNER

University of Chicago, Chicago

In studying the vegetation of the lower Illinois River Valley through four growing-seasons, the author discovered an interesting case of plant succession on the land reclamation levees. As levees ranging in age from one to forty years are found at convenient intervals, one could scarcely ask for a more convenient field for the study of plant succession.

HISTORY OF LEVEE CONSTRUCTION AND LAND RECLAMATION

River floodplains have long been known to contain extremely fertile soil. It is not surprising then that as early as 1893 drainage and reclamation projects were initiated in the Illinois Valley when an extensive drainage district was organized southwest of Havana and a levee was constructed by team and hand labor. It is possible, of course, to farm the bottoms without the protection of a levee and pumps but the proposition is on a sounder footing with these aids. After the first pioneer experiment, levee construction increased rapidly, reaching its height in the Illinois Valley between the years 1902 and 1918. Post-war conditions are probably responsible for the slump that has existed since 1918. However, up to 1930, 339,700 acres had been reclaimed through the organization of sixty-seven drainage districts, forty-five of which are located in the former floodplain of the river. It is not uncommon for a single district to incorporate 12,000 or more acres, and the largest contains 40,760 acres. Most of the leveed districts lie on the east side of the river as the channel occupies the west side of the floodplain throughout most of this range.[1]

Quite significant from the standpoint of the fish and game conservationist is the amount of land in the valley that has not been reclaimed and is still subject to overflow. Some 134,560 acres below Ottawa are still subject to flooding. The bulk of this acreage is included in five unleveed areas of which the most extensive, picturesque, and

[1] Pickels, G. W., and Leonard, F. B., Engineering and Legal Aspects of Land Drainage in Illinois, Illinois State Geol. Survey Bull. 42, 1921 (revised 1928).

interesting is at the mouth of Sangamon River. The others are the Meredosia Bay region, territory above and below Havana on the east side of the river, the area at the mouth of the river, and some territory northeast of Peoria. Some of these areas contain fairly extensive lakes and swamps and retain some of the charm of the primitive state, yet these scattered tracts represent a rather pitiful remnant of what was once one of the finest fish and game areas in America.

FIG 1. *(Above)* Constructing a levee with a dredge boat. *(Center)* Repairing a levee with a caterpillar shovel. *(Below)* A new levee.

DESCRIPTION OF A LEVEED DISTRICT

The area to be reclaimed is surrounded by an earthen wall ranging from eight to twenty-five feet in height, the highest part on the riverward side of the district and lowest part on the opposite side where the land is higher. Modern practice employs a dredge boat in the construction of the levees or, when the ground is dry enough, the caterpillar power shovel is used. The dredge boat floats in the ditch from which the earth is taken to form the levee so that the two operations,

ditch and levee construction, take place simultaneously. Obviously a deep ditch is the constant accompaniment of the levee. Good engineering practice places the outer base of the wall back some five or six feet from the edge of the ditch in order to avoid any slipping or crumbling of the levee when the water is high enough to wash the base. This earthen shoulder, or "berme," as it is named is a rather important feature in later plant succession as it is here that the first trees usually become established.

The outer, or riverward wall of the leveed district may be within twenty-five yards of the river channel, roughly approximating in its course the natural contours of the river. Not only land subject merely to periodic overflow, but also areas formerly occupied by lakes and marshes have been reclaimed. This is all very creditable but as a consequence there is relatively little territory left between the levees and the river channel, even though some of the reclaimed land is of questionable value for agriculture. Possibly it might have been better if a wider fringe had been left, not only for the reason suggested above but also that this strip might more profitably be occupied by lakes and swamps that would function as game preserves.

Plant Succession

Introduction

In making this study of plant succession the location and age of levees was first determined. This was done through the aid of a very excellent and pertinent publication, "Land Drainage in Illinois."[2] It was essential to know not only when a levee was originally constructed but also if it had been repaired and when. By employing a motor boat it was possible to visit levees throughout a range of one hundred fifty miles. The study included observations of the levees throughout the summers of three years and from April to November of 1930.

Actual counts were made, or line quadrats run in order to determine the dominance or relative importance of species. Gray's New Manual of Botany, 7th Edition is the authority for the species named.

Throughout the range studied the common type of soil forming the levees is a mixture of alluvial material containing some rocks, gravel, and mollusk shells. It is slightly alkaline, results of tests ranging from pH. 7.2 to 8.0. As these levees were built in widely separated areas it might be expected that there would be differences in the character of the alluvial soil employed. In general these differences were inconsequential. It is well known that the moisture-equivalent of soils,

[2] Pickels, G. W., and Leonard, F. B., Op. cit.

as computed by the centrifuge method, gives a useful summary of the condition of soils in relation to plant needs (exclusive of nutritional needs, of course, which is certainly not a functional variable here). Examination of soil samples taken from many levees indicates that the moisture-equivalent of levee soils does not vary more than 2 per cent. The wilting coefficient of the same soils ranges from 13.5 to 16 per cent. These facts seem to corroborate the statement that soil differences are neglible in importance at least within the range studied. Soil moisture during the growing season of 1930 was as follows:

	April	May	June	July	Aug.	Sept.
Adjacent floodplain forest soil..	30.9	20.0	21.0	20.2	18.7	24.4
Lower third of levee.....	17.8	19.7	16.5	18.0	9.8	18.6
Middle third of levee.....	14.8	14.7	20.1	13.1	7.8	17.7
Levee top.....	15.3	9.0	16.5	9.2	7.0	10.5

The above analysis was made on a levee on which the middle stages of succession were taking place, that is, the plant cover was made up of herbs, shrubs, and small trees. Soil moisture determination was also made on a levee on which the sub-climax was present, that is, the cover was made up of full-sized trees. In this instance the percentage of soil moisture averaged three points higher in all stations throughout the season. In both cases the soil samples were taken at a foot from the surface.

It will be noted that the soil moisture at a foot in depth on the levees fell considerably below the wilting coefficient (average 14.7) during the latter part of the summer. In considering the effect of this dry condition on the plants of the levee it is of course recognized that most of the roots penetrate much deeper into the soil than this. The effect on seedlings would doubtless be critical, particularly if the condition obtained year after year, but in this connection it will be recalled that the season of 1930 was much dryer than the average.

As the soil is thrown up by the shovels in building the levees it is thoroughly saturated with water and this together with its fine texture establishes poor aeration. It dries and bakes somewhat the first season but continued contact with the air and the ramification of plant roots soon convert it into a reasonably favorable edaphic habitat.

Pioneer Stage of Plant Succession

(One to three years)

Almost all circumstances are favorable for the quick establishment of plants on the new levee. The soil is very soon in a favorable condition, its moisture is usually sufficient, and light, humidity, and air movement all favor plant growth. Furthermore the very-necessary

seeds or propagules are soon brought in by flood water. It is not at all surprising then that plant succession and the establishment of the climax is rapid.

The first plants occurring on the new levee in the order of abundance are as follows: *Amaranthus blitoides* Wats., *A. retroflexus* L., *Erigeron canadensis* L., *Lactuca scariola* L., *Acnida tuberculata* Moq., *Xanthium canadense* Mill., *Chenopodium album* L. and *C. murale* L. Of second rank are: *Ambrosia trifida* L., *Polygonum lapathifolium* L., *P. Pennsylvanicum* L., and *Rumex crispus* L. A third group made up of species somewhat less common is as follows: *Eupatorium serotinum* Michx., *Echinochloa crusgalli* (L.) Beauv., *Radicula palustris* (L.) Moench., *Ambrosia bidentata* Michx., *Lippia lanceolata* Michx. , and *Mollugo verticillata* L. Seedlings of trees appear at this time also. They commonly occur in rows where successive high water levels leave the seeds in the spring. It is quite significant but not surprising that both the levee subclimax and the climax tree species start along with the pioneer group. Seedlings of *Acer saccharinum* L., *Populus deltoides* Marsh., *Ulmus americana* L., *Salix nigra* Marsh., *Salix amygdaloides* Anders., *Salix longifolia* Muhl., and *Salix fragilis* L. are abundant in this early stage. Less commonly are found those of *Fraxinus pennsylvanica* Marsh. var. *Lanceolata* (Borkh.) Sarg., *Platanus occidentalis* L., and *Celtis occidentalis* L. The seedlings of two shrubs that play an important rôle in the middle stages of succession, namely *Sambucus canadensis* L. and *Rhus glabra* L., occur to a considerable extent at this time.

The condition described above persists for three or four years during which time the trees and shrubs rapidly increase in size, particularly the elder, sumach, willow, and cottonwood. As the sprouts of these species attain a height of five or six feet their shade begins to have its influence on the herbaceous plants and this heralds the next phase of the succession.

Second Stage

(Three to six years)

The woody growth as far as species are concerned remains essentially the same at this stage with the exception of a few vines which now become established. This group includes *Tecoma radicans* (L.) Juss., *Vitis vulpina* L., *Celastrus scandens* L., and *Clematis Pitcheri* T. & G. Also, *Hibiscus militaris* Cav., *Adelia acuminata* Michx., and *Cephalanthus occidentalis* L. sometimes become established at the water's edge. The significant change which begins in this period is in

the herbaceous growth which from now on becomes more shade-tolerant, made necessary by the increasing size of the woody plants and the accompanying shade increment. The herbs at and immediately above the water line remain essentially the pioneer group because this area is annually inundated and the herbaceous growth is destroyed. On the upper part of the levees the following plants appear: *Ipomoea pandurata* (L.) G. F. W. Mey., *Convolvulus sepium* L., *Epilobium densum* Raf., *Phytolacca decandra* L., *Gonolobus Laevis* Michx., *Capsella Bursa-pastoris* (L.) Medic., *Amphicarpa monoica* (L.) Ell., *Asclepias tuberosa* L., *Teucrium canadense* L., *Potentilla monspeliensis* L., *Oenothera biennis* L., *Polanisia trachysperma* T. & G., *Cassia Chamaecrista* L., *Cassia Chamaecrista* L. var. *robusta Pollard.*, *Verbena stricta* Vent., and *Oxybaphus nyctagineus* (Michx.) Sweet.

This phase persists for four or five years. During this time the habitat is further modified by the growing trees, and the soil is improved by the accumulation of a small amount of humus. In general the vegetation becomes somewhat more mesophytic and less xerophytic due to the increased water-holding capacity of the soil and to the greater humidity of the air caused by impeded air movement.

Third Stage

(Six to ten years)

Significantly, by the beginning of the third stage the shrub and tree cover (sumach, willow, cottonwood) has so increased that some of the shade-tolerant floodplain forest vines and herbs can gain a foothold. Among these are: *Menispermum canadense* L., *Rhus Toxicodendron* L., *Smilax rotundifolia* L., *Smilax hispida* Muhl., *Smilax herbacea* L., *Cissus Ampelopsis* Pers., *Vernonia missurica* Raf., *Vernonia illinoensis* Gleason, *Bidens* spp., *Amsonia Tabernaemontana* Walt., *Solanum nigrum* L., *Anemone canadense* L., *Asclepias syriaca* L., and *Oxalis corniculata* L.

Fourth Stage

(Ten to fifteen years)

Within the following four to six years two important things take place, the establishment of a more mesophytic herbaceous flora and the beginning of the struggle for supremacy among the trees. Under the first item the herbs coming in or becoming better established are, *Amorpha fruticosa* L., *Cassia* spp., *Apios tuberosa* Moench., *Lysimachia terrestris* (L.) BSP., *Stachys Nuttallii* Shuttlw., *Cicuta maculata* L.,

and *Viola* spp. The soft maple and the American elm begin to be prominent and the willow and cottonwood begin to decline. Occasional ash, sycamore, pecan, hackberry, and pin oak trees which have matured more slowly are found on the upper part of the levee, and the honey locust occurs rarely at the water's edge.

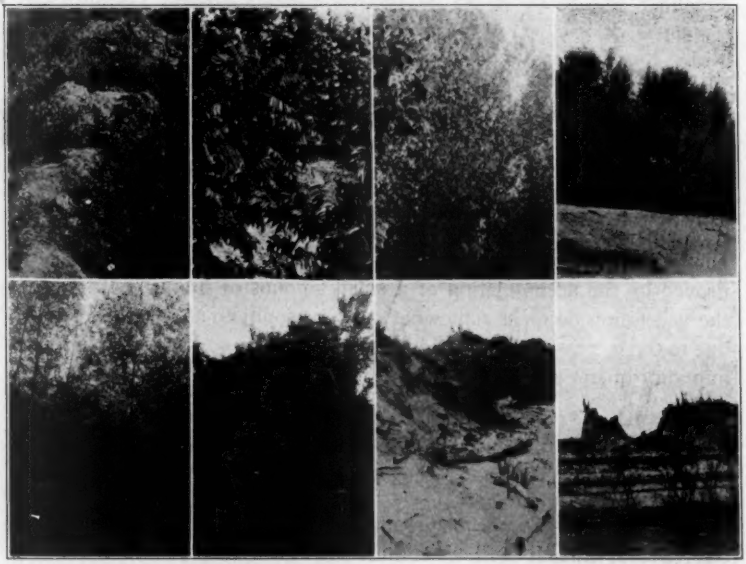


FIG. 2. *(Upper row)* (1) First stage of plant succession, weeds and tree seedlings; (2) second stage, shrubs and tree sprouts; (3) third stage, sumach, cottonwood, and willow; (4) fourth stage, beginning of the elm-maple era. *(Lower row)* (1) Fourth stage, advanced, elm-maple; (2) the climax, elm-maple; (3) A sand levee destroyed by waves (1927 floods); and (4) an unforested dirt levee destroyed by 1927 floods.

FIFTH STAGE

(Fifteen to thirty years)

In the subsequent ten or fifteen years the tendency among the trees is toward the elimination of the less shade-tolerant cottonwoods and willows and the establishment of the maple and elm as dominant. An analysis of the woody flora shows the following proportion of species:

	Per cent
Ulmus americana L.	44
Acer saccharinum L.	32
Platanus occidentalis L.	7
Salix spp.	7
Populus deltoides Marsh.	5

Celtis occidentalis L., *Quercus palustris* Muench, *Betula nigra* L., *Fraxinus pennsylvanica* Marsh var. *lanceolota* (Borkh.) Sarg., and *Carya illinoensis* (Wang.) K. Koch. comprise collectively the remaining five per cent.

Rhus glabra and *Sambucus canadensis* remain rather important locally where they may occur as dense, exclusive colonies. The vines, *Vitis vulpina, Cissus ampelopsis, Psedera quinquefolia* (L.) Greene, and *Smilax* spp. persist as an important accompaniment of the tree stand.

Those levees on which this normal succession is allowed to take place develop a thick stand which so diminishes the light that the herbaceous growth is greatly reduced and modified in regard to species. *Laportea canadensis* (L.) Gaud., *Galium Aparine* L., *G. circaezans* Michx., *Impatiens biflora* Walt., *Viola cucullata* Ait., *Companula americana* L., *Hydrophyllum virginianum* L., *Cirsium virginianum* (L.) Michx., *C. muticum* Michx., and species of Aster and Solidago are prominent herbs in this phase of the succession.

Levee Climax

(Thirty to fifty years)

Although it is somewhat hazardous to state the exact nature of the climax on the basis of forty years' growth it seems probable that it is characterized as follows: the elm becomes relatively more prominent and constitutes from 50 to 65 per cent of the total stand. This is due very largely to the decline of the soft maple (now only 25 per cent) which has a higher mortality rate on the levees and in other ways does not seem to be able to compete so successfully with the elm as it does in the floodplain forest, as described by Turner.[3] The cottonwoods also die out and do not reproduce well and hence comprise only about 2 per cent of the total. The ash, sycamore, pin oak, hackberry, birch, willow, and pecan persist, comprising about 2 per cent each. The herbaceous growth remains essentially the same in quality but decreases in quantity, particularly in the summer and fall species.

Discussion

Exceptions to the foregoing scheme occur of course. Several events may interrupt the normal succession, such as, mowing, fires, grazing, cutting of trees, and floods. Mowing and grazing, and also burning are very common practices as it is the opinion of many ranch

[3] Turner, L. M., Ecological Studies in the Lower Illinois River Valley, Illinois Nat. Hist. Survey, Unpublished Mss.

managers that herbaceous growth such as grasses makes the most effective levee protection. This may be true, but the establishment of a good grass stand on the levee is quite a problem under circumstances that are so favorable to weed, shrub, and tree growth. Unfortunately the grasses that are common to the floodplains, such as *Spartina Michauxiana* and species of *Panicum,* do not thrive and hold their own on the well-drained levee. Taking all things into consideration it is the opinion of the author that the normal climax would be about as economical and effective as any other cover. Perhaps the ideal condition would be a thick stand of trees on the berm and lower outside for wave and ice protection and an herbaceous cover of bent grasses, etc., for the upper and inside parts.

Some ranchers fear that a tree growth would produce large roots which on rotting would facilitate crumbling and leaking of the levee during high water. It is doubtful if this would actually occur. At any rate it would seem that the protection from wave action afforded by trees during flood times would compensate for almost any objection that might be raised against them.

Conclusions

1. Plant succession on the levees of the lower Illinois River Valley occurs in a series of comparatively rapid stages. The levee climax is probably attained within fifty years.

2. The type of succession is secondary—that is, the original floodplain climax is destroyed by the levee construction which creates a different, less mesophytic habitat and the floodplain species adapted to this new habitat become established thereon.

3. Elm and maple are the dominant species of the climax; six to eight other trees persist but are not important in the final association.

4. The herbaceous growth in the climax is limited to a few of the floodplain forest species.

5. Due to several factors the normal succession is not commonly allowed to proceed to the climax.

6. The normal climax probably affords the best cover for the protection and maintenance of the levees.

A PRACTICAL DRIER FOR BOTANICAL SPECIMENS

BY

J. T. BUCHHOLZ

University of Illinois, Urbana

Several kinds of drying apparatus for botanical specimens have ben described at various times. The one concerned in this account has been in use in the botanical laboratories of the University of Arkansas since 1921. It was designed by the writer for the purpose of affording a drying apparatus with a circulation of warm air passed through a plant press employing corrugated paper separators. This form of drier was developed after considerable experimentation with various designs, is free from fire hazard, and is easily adjusted for use, whether a large bundle of plants is to be dried or only a few specimens.

The apparatus as described here is of duplex form, having two complete units built into a single piece of equipment. Air, warmed with mazda lamps which are placed at some distance from the specimens, may be distributed uniformly to all parts of the plant press. An important feature is a safety gauze of ¼ inch galvanized wire, which serves to protect the lamps should the bundle become untied and the specimens or other inflammable material fall down on the lamps.

The receiver shown for holding the press full of specimens has many advantages. It has sloping sides (figure 1, upper left) in the form of a hopper with one end fixed and the other adjustable. When only a few specimens are to be dried, the press is placed edgewise directly on the gauze, and the loss of warmed air passing outside of the corrugated driers may be checked by the use of rolls of paper or towels. If the plant press contains several dozen specimens, it will automatically fit somewhere into a higher position in the hopper. The sloping sides tend to hold the bundle tightly enough to compensate for shrinkage of the press as the specimens dry. If a similar pressure is desired on the upper edge of the plant press, this may be obtained by suspending two moderate weights from cords fastened by means of hooks, with the cords crossing over the top to the weights on opposite sides. The adjustable end assists in the insertion and removal of the press and is pushed in during the operation to prevent leakage of warm air around the end. This arrangement will receive a bundle of plant specimens which stacks 16 inches thick when tied. By placing

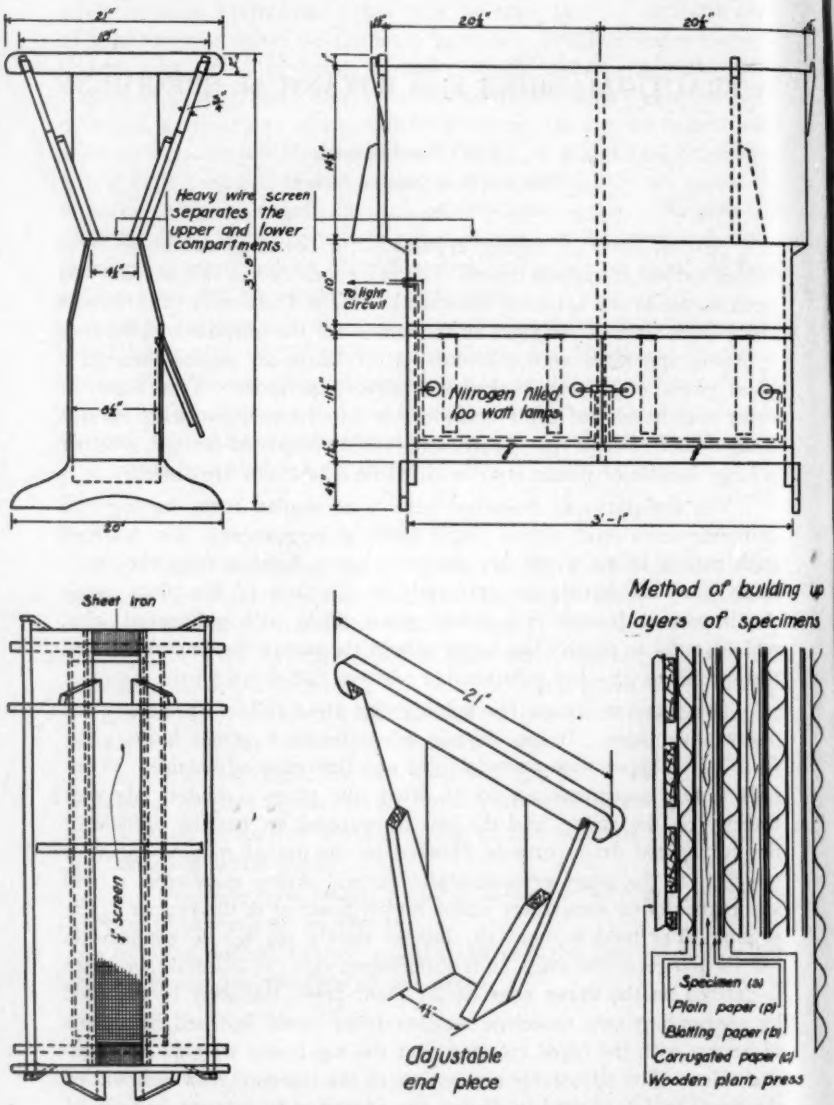


FIG. 1. *Above*—Design of plant drier, end and side views; dimensions are given in inches. *Below*—Top view of hopper showing ¼-inch screen gauze, adjustable end piece, and the proper method of building up a press using corrugated separators.

the press or several plant presses across the top of the hopper, 20 inches of the thickness may be accommodated in each unit, and with the duplex arrangement shown in the accompanying plan of construction, one has available a capacity for drying more than 100 plants as rapidly as only a few.

The accompanying drawings of the plan will serve as a sufficient guide so that a mechanic of average intelligence may construct this apparatus. The correct dimensions are given on all parts, as the drawing was not made and reproduced strictly to scale. The essentials include two flues, one for each unit, 24 inches high and 8½x18 inches in section, in which lamps are installed. The upper ends of the flues narrow down to 4½ inches at the place where the ¼-inch galvanized safety gauze is inserted and the hopper begins. This narrowed throat serves to deflect a part of the air current and tends to spread it slightly within the hopper. The hopper is 4½ inches wide below, widens to 16 inches at the top (inside dimensions), and is 20½ inches long, projecting slightly beyond the flue in order to give space for the adjustable end piece. The piece of sheet iron (fig. 1, lower left) is a stop for stray air currents beyond the end piece when pushed in, but this part may be attached to the bottom of the adjustable end piece or it may be replaced by a small block of wood. Hinged doors permit easy access to the electric lamps which may be turned on and off as occasion requires. In dry weather a single lamp is usually sufficient to dry the plants; in damp, rainy weather both lamps should be used. Various other forms of electric heaters have been suggested, but I have preferred lamps since it was found that the 100-watt, nitrogen-filled mazda bulbs develop about the proper amount of heat to give satisfactory circulation of the air, and when lamps are used there is never any question as to whether the apparatus was left turned on or off.

The height or length of the flue here given was found after several trials to be most desirable. Earlier, in 1919, a low form of this type of apparatus was constructed in which the plants were brought down close (within 5 inches) of the electric bulbs, when the plant bundle rested on the gauze. This form of apparatus, although it dried the plants fairly well, did not give the even distribution of heat and heated air which was found in the apparatus made two years later with a 24-inch flue. Apparently it depended too much upon a smaller volume of heated air, rather than a larger volume of well circulated warm air. After the form described here was found to be an improvement over the low form, a tall form with a flue 3½ feet high was constructed. This apparatus was also somewhat less satisfactory, but is still in use. Altogether, the form with dimensions and proportions as described here

was found to be the favorite drier and was somewhat more practicable than the other two types. Plants may be dried between morning and evening, or over night. As a piece of laboratory equipment, this drier is ideal. It is not a portable drier, but it would seem that anyone with a little mechanical ingenuity might take the dimensions here given as a guide in the construction of a lighter piece of similar apparatus, perhaps making it out of wall board, which could be quickly set up or knocked down and packed into a trunk.

This piece of apparatus which can be constructed from stock lumber by an ordinary mechanic, is relatively cheap, and very simple in operation. The greatest item of expense is the corrugated separators. We found it economical to purchase the corrugated paper in 250-foot rolls 1 yard wide. A common brand called Ridgeway corrugated paper comes in several grades of which the single faced "straw back" weighing 70 pounds per roll is desirable. Any printer or paper dealer will know where to place such an order. The cost per roll need not exceed $4.00 to $4.50 at current prices, and may be cut into about 560 separate pieces 16 inches long and 11½-12 inches wide. The single-faced corrugated paper is as satisfactory as the double-faced but should be used in conjunction with blotters. The lower right-hand diagram shows how they may be stacked in filling the press. A plant specimen is placed between single folds of newspaper, this between two blotters, each specimen being separated from its neighbor by a single corrugated sheet. When the corrugations become dented there is still air space between the blotter and the corrugated sheet.

The blotting paper (sheets 11x16) supplied by the paper dealer should be cut to desired dimensions by the printer. Blotters for drying plants need not be thicker than the ordinary office blotter stock.

A hint as to a simple and easy method of cutting the corrugated paper roll into sheets may be appropriate here. If some of the paper is unrolled and then rolled back into a small, more compact roll about 12-14 inches in diameter, tied with stout cords at the middle and toward the two ends, it may be cut into three small rolls 11½ or 12 inches wide with an ordinary cross-cut saw. If desired, a special miter box may be constructed for sawing the rolls with greater convenience and accuracy. The paper in small rolls may then be cut into 16-inch lengths with a large knife. This treatment does not crush or damage the corrugations at the edges of the sheets. The separators need not be more than 11-11½ inches wide so that one may cut the ends off the rolls if it seems desirable to discard the damaged edges of the original roll.

Several types of plant drier based upon the principle of utilizing artificial heat and corrugated separators between the blotters have been described. There is nothing new or novel in this general method which has been in use for twenty-five years at least. However, several of these types of driers embody a design which brings the specimens into very close contact with the source of the heat. The type here described utilizes convection currents of air only slightly warmed, has a range of adjustment to accommodate from a few to more than 100 plants, is economical of construction and operation, and is safe from fire. Its successful use for more than ten years has fully demonstrated its practicability.

LIFE-FORMS OF ILLINOIS PLANTS

BY

S. JUDSON EWER

University of Illinois, Urbana.

INTRODUCTION

General Concept

A plant, growing under natural outdoor conditions, is continually being acted upon by numerous and varying environmental stimuli. As a response to these surrounding influences the plant assumes a certain external appearance or form which has been termed the "life-form."

Historical

Miss Ennis [3], in her work upon the Connecticut flora, discusses fully the history of the life-form concept from the time of Theophrastus to the present day. Only a brief summary need be given here.

The form of the plant was first considered chiefly from the viewpoint of systematic classification. Although environmental relationships were recognized by the early botanists they were not thought to be important, and very little attention was devoted to them. In 1805, however, Humboldt pointed out the relationship of physiognomy to distribution, and showed that the vegetation of two regions with similar environment was similar in form.

Later, Warming noted certain characteristics of the individual plant which adapted it to its surroundings and which could be set apart from those characteristics of plainly taxonomic value. Thus the form of the plant as caused by the action of environmental factors was recognized, and the concept of the "life-form" elaborated.

Warming and other workers in the ecological field (Drude, Pound and Clements, Raunkiaer, and Gams) have developed systems for the classification of plants according to their life-form characteristics. The most widely used of these systems is that of the Danish botanist, Raunkiaer, presented in detail in 1905 (Bull. Acad. Roy. d. Sci. de Denmark, pp. 347-437).

Raunkiaer's Life-Form System

Raunkiaer's system for the classification of plants according to their life-forms has as its fundamental idea a representation of the climate of a region as evinced by the character of the plant life of that region. The varying degree of protection afforded to the perennating or dormant bud is considered as the adaptive feature, and with this as a basis the following five classes of plants are recognized:

1. **Phanerophytes (Ph). Trees and shrubs, the perennating buds are freely exposed; characteristic of tropical and sub-tropical regions.**
   a. **Megaphanerophytes (Mg). 30 m. or more in height.**
   b. **Mesophanerophytes (Ms). 8 m. to 30 m. in height.**
   c. **Microphanerophytes (M). 2 m. to 8 m. in height.**
   d. **Nanophanerophytes (N). Less than 2 m. in height.**
2. **Chamaephytes (Ch). Plants with the perennating buds either at the ground level or not more than 25 centimeters above it; characteristic of regions with a long winter period.**
3. **Hemicryptophytes (H). Plants with the perennating buds in the upper layer of the soil; characteristic of temperate climates.**
4. **Cryptophytes (C). Plants with the perennating buds in the deeper soil layers or protected by water; characteristic of regions with a season of drought or cold.**
   a. **Geophytes (G). Land plants whose perennating buds are buried in the soil.**
   b. **Helophytes. Marsh or water plants whose perennating buds are in soil or water.**
   c. **Hydrophytes. Submersed aquatics, the perennating buds covered by water. Helophytes and hydrophytes (HH) are usually considered together.**
5. **Therophytes (T). Annual plants, characteristic of regions of intense heat and also of cultivated areas.**

The Life-Form Spectrum

To obtain what is known as the life-form spectrum for a specific region, the flora of that region is classified into the above life-form groups and the percentage of each group is determined. This results in a series of percentages known as the "spectrum." Since the degree of protection offered the perennating bud varies according to the climate of the region under consideration, the percentages of the life-form classes will also vary, and the dominance of a particular life-form class will serve as an index to the general environmental conditions.

Raunkiaer, as summarized by Smith [12], recognizes three climatic zones:

1. **Tropical regions with uniform high temperature and varying humidity; dominated by phanerophytes.**

2. **Regions of decreasing warmth correlated with differences between summer and winter, but where the precipitation is usually favorable for plant growth; dominated by hemicryptophytes.**
3. **Regions of further decreasing warmth and less precipitation; dominated by chamaephytes.**

The Normal Spectrum

In order to have some standard as a basis for comparison, Raunkiaer has devised what he calls the "normal spectrum." This is best summarized in the words of Smith [12] as follows:

"The normal spectrum is the base-line, and the outstanding features of the other spectra are deduced by comparison, not by the highest percentages in their own curves, but by the amount of variation from the normal spectrum. The latter is, ideally, the phyto-climatic spectrum of the whole earth; actually it is obtained by computation and at present is given only as approximate. It was arrived at by first selecting one thousand representative species, and then taking four hundred of these which were carefully analyzed." (See Table II and fig. 2.)

Methods of Investigation

In working out a complete life-form spectrum for a given region it becomes necessary to consider the entire flora of that region from the standpoint of its classification into the various life-form groups. The first phase of the work, therefore, consists in the compilation of a list of plants native to the area under consideration. Such a list of the plants of Illinois was derived from the catalogs and manuals available [1, 4, 5, 7, 8, 10], and although doubtless incomplete, it is probably representative. As Miss Ennis has found that the inclusion of naturalized species "does not materially alter the spectrum," they may be left out of consideration.

In order to make life-form studies of the floras of various portions of the State, Illinois has been somewhat arbitrarily divided into four regions termed respectively: north, central, mid-south, and south, as shown on the accompanying map, figure 1. The division lines have not all been made horizontally across the State, but for the south and mid-south regions have been determined by the last killing frosts of spring and the first killing frosts of autumn [11].

The distribution of the plants in each of these four regions was determined as far as possible from the lists and floras consulted. Where the distribution was doubtful or could not be determined from these sources further data were obtained from examination of material in the herbarium of the University of Illinois.

In the determinations of the life-forms of the various species, free use has been made of previous work upon the subject, of the manuals, and also of the herbarium material. Some determinations are doubtless

Fig. 1. Map of Illinois showing the north, central, mid-south and south regions.

inaccurate, for there was no opportunity to do extensive field work, but as Miss Ennis points out, "a considerable difference in the determination of the life-forms of a region does not materially alter the deduction as to the outstanding features of climate."

In preparing the spectra the following total numbers of native species have been used: total Illinois flora, 1,734 species; north flora, 1,370 species; central flora, 1,227 species; mid-south flora, 891 species; south flora, 905 species; and a combination of the mid-south and south

TABLE I

NUMBERS OF SPECIES OF EACH LIFE-FORM, AND THE ILLINOIS SPECTRA

	Flora	Mg.	Ms.	Mg.-Ms.	M.	N.	M.-N.	Ph.	Ch.	H.	G.	H.H.	C.	T.	S.	E.
No. of Species	T.F.	25	87	112	104	62	166	278	22	862	228	96	324	244	3	1
	N.F.	18	51	69	82	58	140	209	19	686	192	68	260	193	3	
	C.F.	16	52	68	58	30	88	156	10	637	165	60	225	198	1	
	M.F.	20	55	75	45	24	69	144	6	454	112	31	143	142	1	1
	S.F.	23	67	90	56	18	74	164	9	446	109	41	150	135		1
	M.+S.F.	23	70	93	60	29	89	182	10	585	144	56	200	175	1	1
Spectra (%)	T.F.	1.4	5.0	6.4	6.0	3.6	9.6	16.0	1.3	49.7	13.1	5.5	18.6	14.1	0.17	0.06
	N.F.	1.3	3.7	5.0	6.0	4.2	10.2	15.2	1.4	50.0	14.0	5.0	19.0	14.1	0.22	
	C.F.	1.3	4.2	5.5	4.7	2.4	7.1	12.7	0.8	51.9	13.5	4.9	18.4	16.1	0.08	
	M.F.	2.2	6.2	8.4	5.0	2.8	7.8	16.2	0.7	51.0	12.6	3.5	16.1	16.0	0.11	0.11
	S.F.	2.5	7.4	9.9	6.2	2.0	8.2	18.1	1.0	49.3	12.0	4.5	16.5	14.9		0.11
	M.+S.F.	2.0	6.1	8.1	5.2	2.5	7.7	15.8	0.9	50.7	12.5	4.9	17.4	15.2	0.09	0.09

TABLE II

THE NORMAL, ILLINOIS, AND CONNECTICUT SPECTRA

Spectrum	Mg.	Ms.	Mg.-Ms.	M.	N.	M-N.	Ph.	Ch.	H.	G.	H.H.	C.	T.	S.	E.
Normal			6.0	17.0	20.0	37.0	43.0	9.0	27.0	3.0	1.0	4.0	13.0	1.0	3.0
Ill.	1.4	5.0	6.4	6.0	3.6	9.6	16.0	1.3	49.7	13.1	5.5	18.6	14.1	0.17	0.06
Conn.	1.5	3.9	5.4	5.8	3.7	9.5	14.9	1.9	49.4	13.2	8.5	21.7	11.7	0.06	0.06

NUMBERS OF SPECIES IN THE SEVERAL LIFE-FORM GROUPS

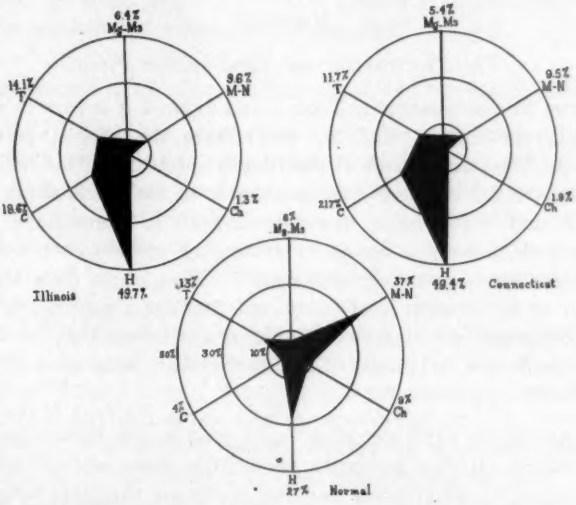
State	Mg.	Ms.	Mg.-Ms.	M.	N.	M.-N.	Ph.	Ch.	H.	G.	H.H.	C.	T.	S.	E.
Ill.	25	87	112	104	62	166	278	22	862	228	96	324	244	3	1
Conn.	23	57	80	85	54	139	219	28	718	192	124	316	170	1	1

Legend for Tables I and II.
T.F. = Total Flora.
N.F. = North Flora.
C.F. = Central Flora.
M.F. = Mid-South Flora.
S.F. = South Flora.
M.+S.F. = Mid-South + South Flora.

Mg. = Megaphanerophytes.
Ms. = Mesophanerophytes.
Mg.-Ms. = Mega-and Mesophanerophytes.
M. = Microphanerophytes.
N. = Nanophanerophytes.
M.-N. = Micro-and Nanophanerophytes.
Ph. = Phanerophytes.
Ch. = Chamaephytes.

H. = Hemicryptophytes.
G. = Geophytes.
H.H. = Helophytes and Hydrophytes.
C. = Cryptophytes.
T. = Therophytes.
S. = Stem-Succulents.
E. = Epiphytes.

floras, 1,154 species. Six different spectra have been prepared, one for the entire Illinois flora, one for each of the four regions of the State, and one for the combined mid-south and south areas. The numbers of species in each life-form group and the six spectra are presented in Table I.



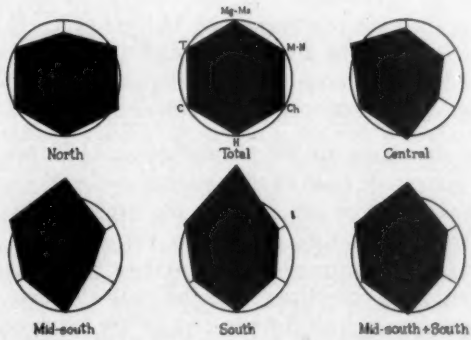


FIG. 2. *(Above)* **Graphic representations of Raunkiaer's normal, Illinois, and Connecticut spectra.**

FIG. 3. *(Below)* **A graphic representation of the life-form spectra of Illinois showing the variations from the spectrum of the total flora taken as a standard.**

As a graphic means of comparing the Illinois spectrum with other spectra, series of concentric circles representing 10, 30, and 50 per cent, have been used, and the percentages of the several life-forms in a cer-

tain spectrum plotted along six radii of these circles, 1 millimeter equaling 1 per cent. By connecting the various points thus determined, a figure is obtained which shows the spectral analysis of the flora under consideration (Fig. 2).

Results

The Spectrum of the Total Illinois Flora

From an examination of Table 1 and figure 2 it is easy to see that the hemicryptophytes (49.7 per cent) have the highest percentage among the life-form groups of the Illinois spectrum. This indicates a temperate climate in which some protection of the perennating buds is required, and thus Illinois would be located in Raunkiaer's second climatic zone, namely, a region of decreasing warmth correlated with differences between summer and winter. Miss Ennis finds the same situation in Connecticut, and points out that the abundance of hemicryptophytes not only suggests an unfavorable season but also that the season is unfavorable because of cold rather than on account of intense heat or xeric conditions.

Cryptophytes (18.6 per cent) rank next to the hemicryptophytes in abundance. In this group the perennating buds are well protected by either soil or water cover and the plants are therefore adapted to rigorous climatic conditions. Of the subdivisions of the group the geophytes are the most prominent with 13.1 per cent. It will be noted that the two groups with the buds protected by either soil or water (hemicryptophytes and cryptophytes) compose considerably more than half (68.3 per cent) of the entire native flora of Illinois.

Next in abundance are the phanerophytes (16.0 per cent). This rather high percentage leads to the assumption that the severity of the unfavorable period does not prohibit the growth of a considerable number of trees and shrubs with freely exposed buds. Among the phanerophytes, the two groups of lower stature (micro- and nanophanerophytes considered collectively) are the more abundant, forming 9.6 per cent as compared with 6.4 per cent of the combined mega- and mesophanerophyte groups. This too is significant in revealing that those phanerophytes with greater bud protection are the more abundant. Of the individual phanerophyte sub-groups, the microphanerophytes are the most numerous (6.0 per cent).

After the phanerophytes the therophytes rank next in abundance (14.1 per cent). Therophytes are adapted to extremely unfavorable conditions, or to regions in a high state of cultivation. Their high per-

centage in the Illinois spectrum further emphasizes the existence of an unfavorable growth period, and also that a large portion of the state is under cultivation.

The other life-form groups are negligible in the Illinois spectrum. Chamaephytes form only 1.3 per cent, while the stem-succulents and epiphytes together make up only 0.23 per cent.

Comparison of the Illinois, Connecticut, and Normal Spectra.

Table II shows the normal spectrum, the spectrum for the total Illinois flora, and that for Connecticut as worked out by Miss Ennis. It also gives the actual number of species in each life-form group in the two states. The Illinois spectrum as compared with the normal shows low percentages of phanerophytes and chamaephytes, and high percentages of hemicryptophytes, cryptophytes, and therophytes. The normal percentage of phanerophytes is nearly three times that of Illinois, and the normal percentage of chamaephytes is approximately seven times as great. The hemicryptophyte percentage of Illinois is nearly double the normal. The geophyte percentage is four times as great. Therophytes are but slightly above the normal. From this comparison it may be seen that the Illinois spectrum has higher percentages of those life-forms with protected perennating buds and thus there is indicated a winter period or unfavorable season for growth and an adaptation to more extreme conditions than indicated by the normal spectrum. The relationship between the two spectra may be seen in figure 2.

A study of the Illinois spectrum as compared with that for Connecticut reveals the interesting fact that the two are almost identical (Table II and fig. 2). This is, perhaps, to be expected as both states have the same general climatic conditions. The percentage of phanerophytes for Illinois slightly exceeds that for Connecticut (Illinois, 16.0 per cent; Connecticut, 14.9 per cent), a condition which is rather striking as Connecticut lies in a generally forested region and Illinois has large areas of prairie. However, the greater north and south extension of the middle western state permits the presence of certain woody elements, particularly southern species, which are not to be found in an area as restricted as Connecticut, but would explain the slightly greater phanerophyte percentage in Illinois.

Chamaephytes have a slightly higher percentage in the eastern state (Illinois, 1.3 per cent; Connecticut, 1.9 per cent). Hemicryptophytes are almost identical in the two spectra. Geophytes are approximately the same, whereas helophytes and hydrophytes are slightly

more abundant in Connecticut (Illinois, 5.5 per cent; Connecticut, 8.5 per cent). The difference here represents the greatest variation of any of the life-form percentages. The difference in therophytes is almost as great, however (Illinois, 14.1 per cent; Connecticut, 11.7 per cent), and is probably indicative of slightly more xeric conditions in Illinois, or larger areas of land under cultivation. Stem-succulents and epiphytes are negligible in both spectra.

Comparison of the Spectra within the State of Illinois.

A comparison of the spectra for the various sections of the State (Fig. 3 and Table I) brings out some rather interesting facts. Most noteworthy, perhaps, is the striking similarity, indicating only slight climatic variations between the different regions. Figure 3 shows the result of attempting to bring out the existing differences by graphic means. The spectrum of the total flora of Illinois has been taken as a standard and a figure representing this made to fill a circle having a 25 millimeter radius. Each of six radii was taken to represent a life-form class and the points where these radii touched the circle were connected. With the resulting figure as a standard, similar figures were constructed for the various spectra within the State showing the variation of these spectra from that of the total flora.

It will readily be seen (Table I) that with the exception of the central region there is a progressive increase in the phanerophytes from the north to the south. In the northernmost region, phanerophytes represent 15.2 per cent, a figure but slightly below that obtained for the phanerophytes of the whole State. There is an increase to 16.2 per cent in the mid-south, and to 18.1 per cent in the south, both of these figures being above the percentage for the entire State (16.0 per cent).

The discrepancy in the successive increase of phanerophytes occurring in the central region, where there are only 12.7 per cent, may be explained, it seems, by the larger proportion of prairie in that region. Prairie conditions are relatively more xeric, the cover being herbaceous and largely composed of hemicryptophytes and geophytes. In this connection it is interesting to note that the hemicryptophytes reach their highest percentage in the central region (51.9 per cent).

As phanerophytes become more abundant in the south where climatic conditions are less extreme, their successive increase from the northern to the southern portion of Illinois is to be expected. In a state with a north-south extension of three hundred eighty-five miles there is certain to be sufficient variation in temperature and rainfall

to assure a more temperate climate in the southernmost portion. That such climatic variation actually does occur may be seen from Table III in which rainfall and temperature data have been assembled from Mosier [9] covering approximately the regions used in this study. These figures show a successive increase in both temperature and rainfall averages from north to south.

TABLE III

AVERAGE RAINFALL AND TEMPERATURE DATA FROM ILLINOIS, 1876-1915

Region	Rainfall Inches	Temperature Degrees
Entire State	38.87	53.45
North	34.12	48.2
Central	36.89	52.4
Mid-south	41.18	55.3
South	43.28	57.9

On account of the similarity between the spectra of the mid-south and south regions, and because the graphs were thought not to show enough difference to warrant the separation of the two, they were combined, and the spectrum of the resulting flora obtained (Table I and Fig. 3). Undoubtedly the most significant result of the union of these two original regions is to be seen in the percentage of phanerophytes. This percentage (15.8 per cent) is less than that of either of the two regions considered separately (mid-south, 16.2 per cent; south, 18.1 per cent), and more nearly approximates that of the north and central portions (north, 15.2 per cent; central, 12.7 per cent). Such an unexpected percentage shows that had not the area been originally divided into two separate sections, the progressive increase of phanerophytes from north to south would have been but slightly apparent. It is a well-known fact that there are certain trees common in the southern states, such as *Nyssa aquatica, Taxodium distichum, Aesculus pavia,* and *Quercus phellos* which occur only in the very southern portion of Illinois. This fact is corroborated by the rise in the phanerophyte percentage in the extreme southern region.

The cryptophytes reach 17.4 per cent in the combined southern portion of the State. This is a figure above the percentage for that life-form group in either the mid-south or south regions. The other life-form percentages seem not to differ in any important way from the corresponding percentages in the mid-south and south spectra. On the whole the spectrum of the combined areas gives percentages more nearly in accord with those of the north and central spectra, thus bringing more uniformity to the spectra of the regions within Illinois.

In Table IV the trees, shrubs, and woody vines are considered as to actual numbers and percentages of species. Although the successive increase of woody plants from north to south is not always clear within each group, it is evident that, in general, such an increase occurs. A glance at the column for trees shows the increase in the mid-south and south percentages. Evergreen trees and shrubs make up but a small percentage of the Illinois flora and occur mostly in the north. Here again the percentages obtained for the combined mid-south and south areas do not show as strikingly the increase of woody elements in the extreme south.

TABLE IV

NUMBERS AND PERCENTAGES OF TREES, SHRUBS, AND VINES

For All Woody Plants

Flora	Total		Trees		Shrubs		Vines	
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
Total	272	15.7	153	8.8	89	5.1	30	1.7
North	206	15.0	107	7.8	82	6.0	17	1.2
Central	156	12.7	87	7.1	47	3.8	22	1.8
Mid-South	144	16.2	95	10.7	35	3.9	14	1.6
South	163	18.0	113	12.5	28	3.1	22	2.4
Mid-South+South	181	15.7	118	10.2	41	3.6	22	1.9

For Deciduous Woody Plants

Total	261	15.0	148	8.5	83	4.8	30	1.7
North	196	14.3	103	7.5	76	5.5	17	1.2
Central	155	12.6	86	7.0	47	3.8	22	1.8
Mid-South	141	15.8	93	10.4	34	3.8	14	1.6
South	161	17.8	111	12.3	28	3.1	22	2.4
Mid-South+South	178	15.5	116	10.1	40	3.5	22	1.9

For Evergreen Woody Plants

Total	11	0.6	5	0.3	6	0.3
North	10	0.7	4	0.3	6	0.4
Central	1	0.08	1	0.08		
Mid-South	3	0.3	2	0.2	1	0.1
South	2	0.2	2	0.2		
Mid-South+South	3	0.3	2	0.2	1	0.1

Turning now to a consideration of the chamaephytes it is seen that the greatest percentage (1.4 per cent) is in the north. The percentages decrease successively in the central and mid-south (0.8 per cent and 0.7 per cent respectively) with a slight increase to 1.0 per cent in the south. This latter increase may possibly be correlated with the presence of considerable hill country in southern Illinois. Chamaephytes are typically a northern group and their greater abundance in the northern part of the State is to be expected.

Hemicryptophytes are the dominant group in all spectra. They are well represented in the north (50.0 per cent), and attain their highest percentage in the central region (51.9 per cent). This increase over the north seems coincident with the drop in the percentage of phanerophytes discussed above, and would appear to indicate slightly more unfavorable conditions probably related to more extensive development of prairie. However, the percentages of hemicryptophytes do not vary greatly between any two regions, and it may be said that this life-form group remains fairly constant throughout the State (Fig. 3).

Cryptophytes reach their lowest percentages in the mid-south and south. Geophytes show progressive dropping off from 14.0 per cent in the north to 12.0 per cent in the south. The variation in the helophyte-hydrophyte group shows nothing significant, and would suggest no essential differences in swamp or water conditions throughout the State.

The therophytes are most abundant in the central region, and their rather high percentages in all parts of the State probably indicate the State-wide prevalence of cultivation. Therophytes are fewest in the north (14.1 per cent), and are fairly well represented in the central, mid-south, and south (16.1 per cent, 16.0 per cent, and 14.9 per cent, respectively).

Stem-succulents and epiphytes are negligible throughout the State. All of the former occur in the north, but decrease in the central and mid-south regions. They disappear entirely in the south. The one epiphyte, *Phoradendron flavescens,* occurs in the mid-south and south.

Summary

1. A study of the spectrum for the entire native flora of Illinois reveals a "hemicryptophytic climate" as evinced by the dominance of that life-form group. There is evidence of a season unfavorable to growth due to cold rather than to heat or lack of moisture. This unfavorable period is not extreme as the phanerophytes are fairly well represented.

2. The total Illinois spectrum reveals nearly double the normal percentage of hemicryptophytes; about one-third the normal percentage of phanerophytes; four times the normal percentage of cryptophytes; approximately one-seventh the normal percentage of chamaephytes; and a percentage of therophytes nearly the same as that in the normal spectrum. These deviations from the normal indicate the existence of an unfavorable period for growth, as there is an increase of those forms

which are adapted to rigorous conditions and a decrease of those forms which are adapted to warm-temperate or tropical conditions.

3. A comparison of the Connecticut spectrum with that of Illinois reveals a striking similarity. The greatest discrepancies occur in the helophyte-hydrophyte and therophyte groups. The higher percentage of therophytes and the lower percentage of helophytes and hydrophytes are probably correlated with slightly more xeric conditions and greater cultivation in the western state. The slightly greater abundance of phanerophytes in the middle western states is to be associated with the greater north-south extension. In general it may be said that the same conclusions drawn by Miss Ennis for Connecticut also hold for Illinois.

4. An examination of the spectra of the north, central, mid-south, and south regions of the State shows that climatic conditions are less severe in the south than in the regions successively north, the greatest variation, of course, being between the extreme northern and the extreme southern portions. This climatic difference is particularly indicated by the increase of phanerophytes from 15.2 per cent in the north to 18.1 per cent in the south. Data upon rainfall and temperature support the results revealed by the plants themselves. Hemicryptophytes show a lower percentage in the south than in any other region, although the highest percentage of these is found in the central rather than in the northern region, seemingly due to extensive prairie in this middle section. Geophytes show the highest percentage in the north with progressive falling off southward, while therophytes indicate nothing significant other than that their abundance points to much cultivated land and to the existence of an unfavorable growth period. The spectrum of the combined mid-south and south regions fails to reveal as strikingly the increase of woody plants in the southern portion of the State, but tends to make the phanerophyte percentages more uniform throughout.

Thanks are due to Dr. A. G. Vestal of the University of Illinois for continued advice and help in the working out of this study, and to Dr. A. R. Kienholz of the Yale School of Forestry for the suggestion of the problem and ever constant encouragement.

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A LIST OF MOSSES FROM VERMILION COUNTY, ILLINOIS

BY

FRANCIS R. GRANT AND STELLA M. HAGUE

University of Illinois, Urbana

The Vermilion River and its tributaries drain the northern three-fourths of Vermilion County and the Little Vermilion the greater part of the southern fourth. The valleys are young and the extensive bluffs have an abundant moss flora.

The mosses here listed were collected in the fall of 1929 and the spring of 1930.

The names used are those found in A. J. Grout's "Mosses with a Handlens and Microscope," and "Moss Flora of North America," Vol. III, part I.

POLYTRICACEAE

Catherinea angustata Brid., October 19.
undulata (L.) W. and W., October 6.
Polytrichum juniperium Willd., May 1.
Ohioense R. and C., September 21.

DICRANACEAE

Ceratodon purpureus (L.) Brid., March 20.
Dicranella heteromalla (L.) Schimp., October 13.
heteromalla Fitsgeraldii R. and C., October 19.
varia (Hedw.) Schimp.
Dicranum. Two species, both sterile, April 16.
Ditrichum pallidum (Schreb.) Hampe, October 5.
tortile (Schrad.) Hampe, October 26.

GRIMMIACEAE

Grimmia apocarpa (L.) Hedw., April 26 and May 5.

TORTULACEAE

Barbula fallax Hedw., October 13.
unguiculata (Huds.) Hedw., October 19.

FUNARIACEAE

Funaria hygrometrica (L.) Sibth., October 19.
Physcomitrichum turbinatum (Mx.) Brid., April 30.

AULACOMNIACEAE

Aulacomnium heterstichum (Hedw.) B. and S., March 30.

BARTRAMIACEAE

Bartramia pomiformis (L.) Hedw., May 4.

BRYACEAE

Bryum caespiticium L., April 2.
Leptobryum nutans (L.) Wils., October 13.
Mnium cuspidatum (L.) Leyss., April 19.
Pohlia nutans (Schreb.) Lindb., April 19.

LESKEACEAE

Anomodon minor (P. Beauv.) Fuern., March 20.
rostratus (Hedw.) Schimp., October 6.
Leskea obscura Hedw., October 19.
polycarpa Ehrh., September 21.
Thuidium delicatulum (L.) Mitt., May 4.

HYPNACEAE

Amblystegium orthocladon (P. and B.) Kindb., April 16.
serpens (L.) B. and S., November 2.
varium (Hedw.) Lindb., April 16.
Brachythecium oxycladon (Brid.) J. and S., April 30.
salebrosum (Hoffm.) B. and S., May 4.
Chamberlainia acuminatum (Hedw.) n. comb., March 13.
Drepnocladus sp., April 12.
Eurhynchium hias (Hedw.) J. and S., October 5.
serrulatum (Hedw.) Kindw., September 21.
Entodon cladorrhizans (Hedw.) C. M., March 30.
seductrix (Hedw.) C. M., March 30.
Hypnum curvifolium Hedw., October 19.
patientiae Lindb., October 26.
Plagiothecium denticulatum (L.) B. and S., October 26.
Platygerium repens (Brid.) B. and S., October 15.

PROGRESS REPORT ON THE WATERMELON WILT PROJECT IN ILLINOIS

BY

J. W. MILLER

Illinois State Department of Agriculture

The soil fungus *Fusarium niveum* E. F. Sm. that causes the disease of watermelons known as "wilt" has become established in all the chief watermelon-growing sections of Illinois as well as in other melon-producing areas throughout the United States. In many sections it has become so serious that it is now a limiting factor in the commercial production of watermelons, and because it is characteristic of the wilt fungus that it can survive in the soil for a period of from fifteen to twenty years in the absence of melons, its control has presented many difficulties.

Such control measures as seed treatment and the application of chemicals to the soil have been tried out with negative results. The only effective method of control has been a period of rotation sufficiently long to permit the dying out of the fungus. It has long been apparent that the most promising control method lies in the production of a variety of watermelon which is sufficiently resistant to the wilt disease to enable the grower to produce a profitable crop on wilt infected soil.

In 1926 the Illinois State Department of Agriculture inaugurated the Watermelon Wilt Project, which had as its primary purpose the development of a wilt-resistant variety of watermelon. An experimental station was established in a large watermelon producing section of the State where the wilt disease had been causing severe losses.

At the outset seeds of all available watermelon varieties were collected, including the citrons, preserving melons, and stock melons. All of these were planted and tested for any possible wilt resistance. It was found that none of the commercial varieties possessed any visible resistance, but that the stock melons were highly resistant. Consequently it was thought that by crossing desirable commercial varieties with the stock melons, a hybrid melon might be evolved which would be wilt-resistant and which could be developed into an edible melon by inbreeding and back-crossing. This had previously been done by

W. A. Orton when he developed the variety "Conqueror," a variety which was not very successful in this State. Although much emphasis has been placed upon this method, the possibility of securing a resistant strain by selection from hills in commercial varieties which have "stood up" on wilt-infected soil has not been overlooked. Unfortunately, however, we have not been able to secure a strain which has proved resistant when later planted on thoroughly wilt-infected soil.

In hybridizing we have been more successful. Out of hundreds of crosses between the Kansas stock melon and commercial varieties, several strains now in the 3F and 4F generations have been secured which possess varying degrees of resistance as well as marked variation as regards to shape, color of flesh, seeds, rind, taste, time of ripening, etc.

At present seven of the hybrid strains appear from all standpoints to be superior to the others. Three of them are the result of crosses between the Kansas stock melons and the variety Halbert Honey, three others are crosses between the Kansas stock melon and the variety Tom Watson, and the seventh is a cross between the varieties Conqueror and Thurmond Grey. All of these strains have been inbred for at least three generations, but certain visible characters have not become "fixed," and with the exception of one strain, each strain includes at least two distinct types. In 1930 these varieties produced from 25 to 50 per cent of a normal crop under the most adverse circumstances where 100 per cent of the standard commercial varieties which were used for checks succumbed to the disease.

Some of the qualities possessed by these strains are very promising but others need much improvement. The flesh color ranges from a light to a deep red, and in the Kansas stock-Halbert Honey crosses the flesh is exceptionally sweet. The rind color ranges from light, striped, and mottled melons to a solid, deep green. The rind is heavy and well adapted for shipping. In shape they range from round to long melons of the Conqueror and Tom Watson types. The two most undesirable qualities are a more or less stringy flesh and lateness in maturing. It is hoped that by back-crossing the hybrids upon the commercial parent and by continued selection these undesirable qualities may be overcome. Whether this can be done without destroying the wilt resistance remains to be seen.

Back-crossing was begun in 1930, but the unusually hot, dry weather severely handicapped the artificial pollination work and only a few melons were secured.

It is interesting to note that the green coloring found in the seeds of the Kansas stock melon is carried over to some extent in the hybrid melons and it is thought that the degree of resistance may be judged by the amount of green coloring found in the seeds of the hybrid melons. Hundreds of hybrid melons whose seeds lack this coloring have shown no resistance to the wilt disease.

At the present time it is not known whether different strains of the causal organism exists in different sections of the country, but we have some slight evidence that such may be the case. If this be true the problem will be even more difficult to bring to completion.

It is believed that great headway has been made towards breeding a new variety of watermelon which will be sufficiently resistant to the wilt disease to enable the growers to produce a profitable crop upon wilt infected soil. As in all work of this nature progress is usually slow and it takes a number of years to work out to a satisfactory conclusion new varieties which possess all the necessary requirements for commercial purposes. However, from what has already been accomplished it would seem that the ultimate aim of this project is not an impossibility and that it may be attained in the near future.

INFLUENCE OF FERTILIZERS UPON THE REACTION OF SOILS

BY

H. J. SNIDER

University of Illinois, Urbana

The crop-producing capacity of agricultural lands in Illinois tends to decrease as the acidity of these soils becomes greater. When accompanied by a low level of production, the acid condition of soils presents a more or less serious economic aspect which requires careful consideration. Large sums of money are expended annually in an effort to overcome soil acidity and the many ills which usually accompany it.

The dropping off in crop returns from farm lands naturally leads to the use of various fertilizers in an effort to keep up the fertility and maintain a relative high level of production. Some fertilizers and fertilizing materials are used with a view of correcting acidity and ameliorating the physical condition of soils, whereas others are used to supply certain plant food elements which may be deficient or not readily available in the soils in question.

Some fertilizers tend to increase the acidity of soils upon which they are used, whereas others act in a reverse manner. Ammonium sulphate, when used in the usual quantities and for a sufficiently long period of time, will increase soil acidity, and sodium nitrate will, under like conditions, increase the alkalinity of soils. Superphosphate 16 per cent grade in a suspension has a pH varying from 3.0 to 5.6, and this material has a slight tendency to increase soil acidity. Rock phosphate in suspension has a pH of approximately 6.4 and has a slight tendency to decrease soil acidity. Fertilizers such as the above named phosphates are used in relatively small quantities in comparison to the volume of soil to which they are applied, so that their effect on soil reaction is not apparent because, usually, there is not enough of the reacting material to overcome the strong buffer action of the soil.

The experimental work here reported consisted of determining the hydrogen ion concentration of the soils from experimental field plots which had been subject to various forms of fertilization for a number of years. The samples of soil upon which the determinations were

made represented the top soil to a depth of approximately seven inches. The pH determinations were made electrometrically, using the quinhydrone electrode.

Table I shows that the only material which made any considerable change in the soil reaction in the Hartsburg field, representing a very fertile soil, was lime treatment which raised the pH from about 6.10 to nearly 7.00, or the neutral point. On this field, manure, residues, rock phosphate, and kainit apparently had no influence on the reaction of the soil.

In the Toledo and Ewing fields (Table I), representing some of the less productive soils, rock phosphate tended to raise the pH. In the four comparisons of these two fields, three showed a slight increase in pH where rock phosphate was used. The use of lime on these two fields was the big factor in bringing the pH up to near the neutral point. Manure, residues, and kainit had no considerable influence on the soil reaction in these tests.

TABLE I.

HYDROGEN ION CONCENTRATION OF SOILS FROM FERTILIZED EXPERIMENTAL FIELD PLOTS

Plot No.	Fertilizer Treatment	Hartsburg Field pH	Toledo Field pH	Ewing Field pH
1.	None	6.10	5.17	5.00
2.	Manure	6.10	5.10	4.83
3.	Manure—Lime	7.03	6.35	7.10
4.	M. L. Rock Phosphate	6.94	6.60	7.28
5.	None	6.18	5.10	5.00
6.	Residue	6.18	5.10	5.10
7.	R. Lime	6.94	6.35	6.86
8.	R. L. Rock Phosphate	6.94	6.35	7.37
9.	R. L. P. Kainit	6.94	6.44	7.37
10.	None	6.42	5.25	5.00

Table II shows comparisons of the effect of rock phosphate and superphosphate when used with a light and a heavy application of lime on the Odin field. On Plot 603, where two tons of lime were used, superphosphate showed a slight tendency toward a more acid condition, whereas the rock phosphate showed a slight tendency toward alkalinity. The margins were very small in both cases. The influence of the rock phosphate on Plot 604 might also be discounted because the subsoil on this plot had a slightly higher pH (less acid) than the surface soil or the subsoils of the other plots in this comparison.

On Plot 803 Table II, where a relatively large quantity of lime was used (eight tons an acre) superphosphate showed no tendency to increase the acidity. The rise in pH on Plot 804 due to the use of rock phosphate showed a very slight tendency to increase the alkalinity of the soil.

In the Odin field experiment (Table II), relatively large quantities of both phosphates were used. In a period of years from 1905 to 1919, a total of fourteen tons an acre of rock phosphate was applied to the land, and during the same period, seven tons an acre of superphosphate were put out. The quantities of the materials used were sufficiently large to show their possibilities in influencing the reaction of the soil.

TABLE II

HYDROGEN ION CONCENTRATION OF SOILS FROM FERTILIZED PLOTS ON THE ODIN EXPERIMENT FIELD

Plot	Fertilizer treatment	pH
2 tons of lime		
602	Lime Kainit	6.01
603	Lime Kainit superphosphate	5.84
604	Lime Kainit rock phosphate	6.18
8 tons of lime		
802	Lime Kainit	7.11
803	Lime Kainit superphosphate	7.11
804	Lime Kainit rock phosphate	7.20

PRELIMINARY REPORT ON THE PALEO-ECOLOGY OF A WISCONSIN AND AN ILLINOIS BOG

BY

JOHN VOSS

Manual Training High School, Peoria, Illinois

INTRODUCTION

An important line of research and one which during the past fifteen years has received the attention of many European botanists, is known as pollen statistics or pollen analysis. Fossil pollen found in peat are generally well preserved even after all of the rest of the plant has decayed. Using the method of pollen analysis, workers in this field are able to trace the history of the vegetation which appeared on or near the bogs since their beginning. Up to the present very little work has been done in North America, the only published material to the author's knowledge being that of Auer who worked in southeastern Canada, of Lewis and Cocke who worked in the Dismal Swamp, and Sears who worked in the Erie Basin. It is the purpose of this paper to present a preliminary account of the pollen analysis of two bogs; one located at Antioch, Illinois, and the other at Waupaca, Wisconsin, one hundred fifty miles north of Antioch.

DESCRIPTION OF THE BOGS

The Antioch bog is located about three miles southeast of the city of Antioch, Illinois, in a region which was traversed by an ice sheet of the Late Wisconsin glaciation. It covers an area of about seven acres, and a portion of it is covered with rather heavy tamarack timber growing on a solid substratum. The vegetation also includes the following: *Betula lutea, Betula pumila, Salix discolor, Pyrus melanocarpa, Pyrus americana, Cornus stolonifera, Populus tremuloides, Prunus serotina, Corylus americana, Corylus rostrata, Gaylussacia baccata, Vaccinium vacillans, Trientalis americana, Onoclea sensibilis, Osmunda regalis, Osmunda cinnamomea,* and *Cystopteris fragilis.*

The Waupaca bog is located about two and one-half miles north of Waupaca, Wisconsin, along the tracks of the Waupaca & Green Bay Railroad. Like the Antioch bog it is also within the limits of the Late Wisconsin glaciation. It covers an area of about sixty acres. The

slope of the sides of the depression forming the bog is about forty-five degrees and although the area is small, the bog is deep. Much water is present, and the soft, built-up character of the Sphagnum makes the surface springy and sponge-like. Upon the surface of the bog the following vegetation is found: leatherleaf *(Chamaedaphne calyculata)*, bog rosemary *(Andromeda glaucophylla)*, Labrador tea *(Ledum groenlandicum)*, blueberry *(Vaccinium canadense)*, small cranberry *(Vaccinium oxycoccos)*, boneset *(Eupatorium perfoliatum)*, fireweed *(Epilobium angustifolium)*, three-leaved Solomon's seal *(Smilacina trifolia)*, pitcher-plant *(Sarracenia purpurea)*, buckbean *(Menyanthes trifoliata)*, mountain holly *(Nemopanthus mucronata)*, meadow-sweet *(Spiraea salicifolia)*, tamarack *(Larix laricina)*, black spruce *(Picea mariana)*, white pine *(Pinus strobus)*, American aspen *(Populus tremuloides)*, black willow *(Salix nigra)*, shining willow *(Salix lucida)*, cotton grass *(Eriophorum virginicum)*, Carex *(Carex trisperma)*, *Scheuchzeria palustris*, and *Scirpus lineatus*.

Peat Classification

If pollen statistics receives the attention in America that it has in Europe, a universal system of peat classification should be adopted. It is for this reason that the writer has adopted Auer's system, a pioneer worker in Canada and one whose work is very extensive. Auer divides peats into four groups.

(1) The limnic (lake) group consisting of all material deposited under water.

(2) The telmatic (marsh) group made up of peat that has developed on wet grounds. *Carex*, *Amblystegium*, and *Sphagnum cuspidatum* belong here.

(3) The semiterrestrial group developed under drier conditions than the telmatic. It is generally homogeneous and made up chiefly of *Sphagnum*.

(4) The terrestrial group composed of various forest peat-bog types and always having the remains of trees in it.

Field Work

Samples of peat were obtained by means of a Hiller peat auger (Fig. 1), for the use of which I am greatly indebted to Dr. George Fuller of the University of Chicago, through whom I first became interested in the problem of pollen analysis. The drill consists of eight sections, each about five feet long, the bottom section having an auger

and a chamber in which the peat is collected. The peat chamber is so constructed that, when the drill is rotated in a clockwise direction, the peat chamber is closed. Upon rotating it quickly about eight times in a counter clockwise direction, the chamber is opened, and a solid core of peat is obtained. To close the container the drill is rotated in a clockwise direction. The auger is then pulled to the surface and by means of a spatula or forceps, the material is carefully removed and

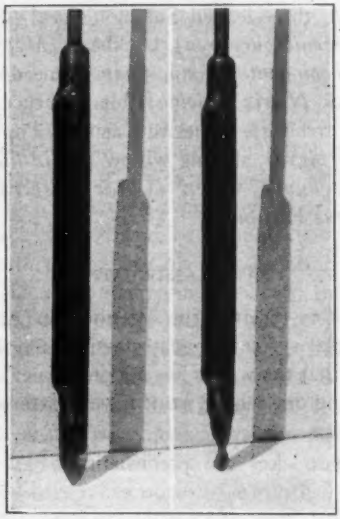

FIG. 1. Hiller peat auger used to collect samples—left, chamber closed; right, chamber open.

placed in numbered glass tubes having a stopper at each end. Borings were made along a line across the longest portion of the bog, the number of drillings and the distance between the drillings depending upon the size of the bog.

LABORATORY WORK

For advice in the method used in the preparation of the microscope slides, the identification, and counting of the pollen, I am greatly indebted to Dr. Fuller of the University of Chicago, Dr. Sears of the University of Oklahoma, and Dr. Erdtman of the University of Stockholm.

Approximately 1 cubic centimeter of material was boiled in ten per cent KOH, centrifuged, decanted, then distilled water was added; it was shaken, and again centrifuged and decanted. By means of a pipette a small quantity of material near the surface of the solid material in the bottom of the test tube was removed and placed on a slide and a warming table, and after most of the water evaporated, glycerine jelly and a cover glass were added. Numerous experiments conducted by Erdtman have shown that reliable percentages are obtained if at least 150 pollen grains are counted in each sample. Figure 2 shows a photomicrograph of a typical slide of treated peat.

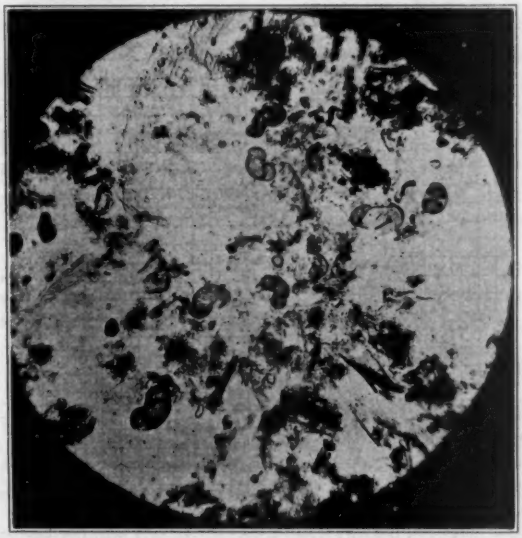

Fig. 2. Photograph of a portion of a typical slide showing pollen grains of some of the conifers.

Results

Figure 3 shows the pollen analysis graph and stratigraphy of the Antioch bog. The numbers to the left represent the depth of the peat in feet and the numbers in the horizontal scale give the percentage of the total tree-pollen. The species of trees are indicated by signs, an index of which is given in the legend. In order to avoid too many lines in the pollen analysis diagram, some of the less common species of trees were omitted.

The bottom one-foot layer consisted of limy ooze. During the early development of the bog, when this material was deposited, Abies and Picea reach their maximum. Above the twenty-one foot level, the peat changes to the limnic type or material deposited under water. In the limnic layer Abies and Picea disappear whereas Quercus, Tilia and Ulmus attain their maximum. Between the ten and eight foot levels the peat is drier and consists chiefly of the remains of plants that grew on wet grounds. Above the eight foot level, the peat is very dry, decomposed, and filled with numerous stumps of trees. As the diagram indicates, Quercus, Tilia, and Ulmus are the predominating trees from the twenty-one foot level to the surface of the bog.

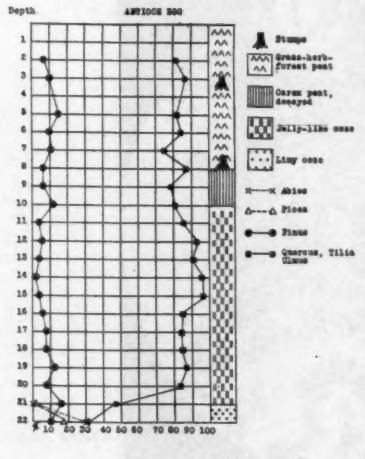
Depth
ANTIOCH BOG
Stumps
Grass-herb-forest peat
Carex peat, decayed
Jelly-like ooze
Limy ooze
Abies
Picea
Pinus
Quercus, Tilia Ulmus
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
% 10 20 30 40 50 60 70 80 90 100

FIG. 3.

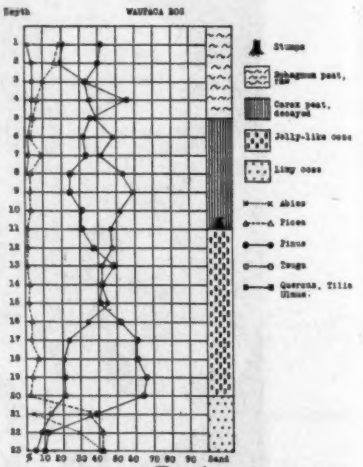

FIG. 4.

Comparing the character of the peat found in the Waupaca bog (Fig. 4) with that of Antioch, one may readily see, as Auer has pointed out in his work on the Canadian bogs, that there are distinct regularities in the stratigraphic development of both bogs. In the Waupaca bog the three foot layer at the bottom consists of the same type of peat found at the bottom of the Antioch bog. Above the bottom three-foot deposit, from the twenty foot level to the eleven foot level, the peat is similar to that above the bottom layer at Antioch. Likewise, decayed Carex peat is found above the limnic peat. The only difference between the two bogs is the presence of a layer of raw Sphagnum peat found above the decayed Carex layer in the Waupaca bog instead of the grass-herb-forest peat as found at Antioch.

As the stratigraphic changes may or may not indicate climatic changes during the post-glacial period, let us compare the pollen diagrams of both bogs for further evidence. It is a well known fact that the distribution of vegetation is dependent upon climatic conditions and according to Auer—"The Pollen content of the successive layers of the individual bogs is a direct indication of the comparative abundance of the different trees growing at the time the peat layers were formed." In the Waupaca bog we find practically the same succession of trees as found at Antioch. Abies and Picea reach their maximum in the bottom layer and are followed by an increase of Quercus, Tilia, and Ulmus in the upper layers.

Considering both sources of evidence, the stratigraphy and pollen statistics, the climatic changes during the post-glacial times may be divided into three periods. The first, when Abies and Picea reached their greatest development, was probably dry and cool. The stratigraphy shows that during the second period a secondary lake spread over the area. The fact that the hardwoods were very abundant, seems to show that the climate was wetter and warmer than during the first or primary lake period.

In both bogs the secondary lakes were overgrown with marsh vegetation. This condition, together with the appearance of tree stumps in this stratum, appears to indicate that the climate during the third period was dry. As Quercus, Tilia, and Ulmus also reached their maximum during this time in the Waupaca bog and likewise were very abundant in the Antioch bog, the climate probably was also warm. The presence of raw Sphagnum in the upper layers of the Waupaca bog may indicate a moist, cool period as Picea slightly increases and the hardwoods decrease.

Whether or not the data presented shows climatic changes since the last glacial invasion, it at least shows the succession of vegetation since that time. In this connection it is of interest to compare the data with some of the theories advanced regarding post-glacial migration of plants. One of the best appeared almost thirty years ago in Transeau's paper dealing with bog plant societies. Figure 5, from Transeau's article, shows the present distribution of the forests, prairies, and plains. What happened to the vegetation when the glaciers covered the northern half of North America, he pictures in Figure 6. In front of the glaciers the vegetation consisted of the tundra type similar to that found at the present time in Greenland and Alaska. South of the tundra, it is likely that the northern conifers appeared, followed by the deciduous forest and southern conifers.

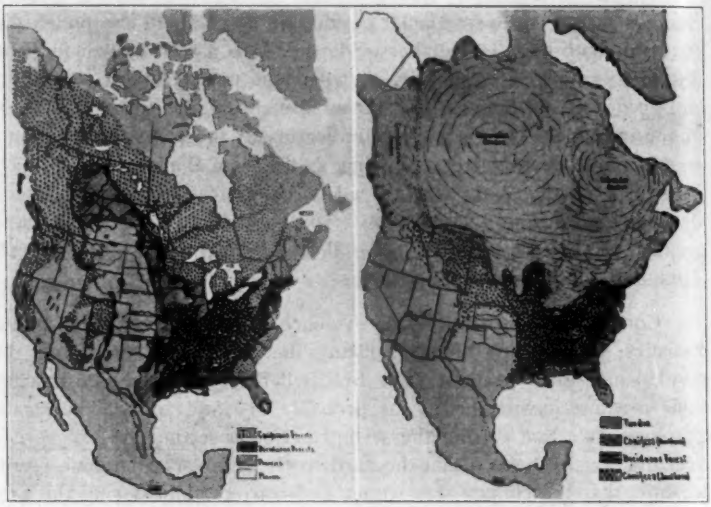

FIG. 5. *(Left)* **Map showing present distribution of forest, prairie, and plains. (After Sargent, 10th Census, Vol. 9.)**

FIG. 6. *(Right)* **Map showing hypothetical distribution of forests and tundra during maximum glaciation of the Wisconsin Epoch. (After Transeau Bot. Gaz., Vol. 36.)**

SUMMARY

1. The Waupaca bog shows four and the Antioch bog three distinct changes in stratigraphic development.

2. The first peat of both bogs was probably formed during a dry, cool period, which was followed by another warm but moist period; as shown by the abundance of broad-leaved trees; this in turn followed by a warm, dry period, and in the Waupaca bog by another apparently cool, moist period.

3. The succession of vegetation appears to have been Abies-Picea, and Quercus-Tilia-Ulmus.

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SOME OBSERVATIONS ON LESPEDEZA IN SOUTHERN ILLINOIS

BY

C. J. BADGER

University of Illinois, Urbana

Lespedeza, commonly known by the name of Japan Clover, is one of the most valuable plants for forage in the southeastern part of the United States. Its wide adaptation to grazing conditions gives it a value that is hard to estimate. It will grow in open woodlands, on the poorest of upland hills, along roadsides, and in other waste places. Being a legume, it is valuable for soil improvement, and also it is relished by all classes of livestock.

Authorities seem to agree that this plant was introduced into the South Atlantic States from Eastern Asia somewhere from 1846 to 1860, the exact date being unknown.

Lespedeza has gradually spread until it occurs in more or less abundance from central New Jersey westward to central Kansas, as far north as southern Iowa, and southward to the Gulf of Mexico. It was limited to a small area in the south before the Civil War, but soon afterward was found in many parts of the South. As horses relish lespedeza, and as the seeds may pass thru the alimentary tract without being destroyed, it is probable that it was widely distributed by cavalry during the Civil War [1]. Other animals and birds may likewise have been responsible for its distribution.

Lespedeza is grown in several counties in southern Illinois. Bond County has had a few acres for six or seven years, one man having grown it mostly for seed, growing from 10 to 20 acres each year. In several other counties, including Massac, Pope, Hardin, Union, White, and Saline, the lespedeza grows naturally upon hillsides, roadsides, and open lands. In Massac County one grower has been cultivating the crop for nearly five years.

Japan Clover or lespedeza, *Lespedeza striata* (Thunb), belongs to a tribe (Hedysareae) which is characterized by the fruit not being a true legume, the pod being divided crosswise by one or more joints (*loment*) [2]. In the genus *Lesepdeza* there is one or more joints. The leaves have three leafllets, the lateral leaflets being on the side of

the leaf stalk *(pinnate)*. About a dozen or more native perennial species are more or less widely distributed.

In manner of growth the lespedeza is a spreading or ascending plant with one to three sessile or nearly sessile pink or purple flowers; its height is usually from 6 to 12 inches, but on rich lowlands it is sometimes 30 inches or more.

It will reseed on the same ground year after year. The seeds are rounded to egg shaped, 0.05 to 0.07 inch long and 0.04 to 0.06 inch wide, and are green, greenish brown, amber, or black in color. They are usually sold in the pod which in turn is enclosed in the calyx. The weight is 25 pounds per bushel of seed.

Lespedeza is best seeded in the spring during late March or early April. It may be put in with oats, seeding immediately after the grain has been covered. Incidentally an excellent stand was obtained in Franklin County this spring using this method. It may also be seeded several days after the grain has germinated. On several of the outlying Experiment Stations of the University of Illinois it has been seeded in wheat as well as in oats with equal success in securing a stand.

From 5 to 10 pounds of seed (preferably inoculated) should be sown to the acre where a full growth is desired that same season. It may be seeded early as there is no special danger from freezing as with young red clover or alfalfa, however it will not start growth until warm weather about April 1st.

Korean lespedeza best produces seed on soil of medium fertility. Increased yields of hay and seed have been obtained which show that the crop will respond to fertilizer treatment [3]. Lespedeza should be cut for seed soon after all the plants have matured and lost their green color, generally in late September and usually after one or two light frosts. Cutting too early results in low quality immature seed, but cut dead ripe there is considerable shattering.

The seed is harvested with a mower; a slotted pan attached to cutting bar saves much of the best seed. After cutting, it is placed in small shocks or stacks and threshed a few days later after it has been allowed to go thru a "sweat". Either a clover huller or a grain thresher may be used to thresh out the seed. Yields in Southern Illinois of from 100 pounds or less up to 300 pounds per acre have been obtained. The price of the seed ranges from 30 to 50 cents a pound.

Lespedeza is generally adapted to all soils in the State. It is known to grow well on acid soils, on poor yellow to red clay hill soils, and also on sandy soils. Like most other crops it thrives better on fertile soils.

The chief uses of lespedeza are for pasture, soil improvement, and seed production. It also makes fair hay. One great benefit noted for this new legume is its ability to become established on worn or abandoned land. Once it becomes established it will afford more pasturage than can be obtained from any other legume without costly soil fertilizing. The erosion of idle land may be gradually stopped by the growth of this plant.

Lespedeza can be and is being grown to advantage on many soils where production of clovers is difficult and impractical. It may be sown in small grain crops, in grass-clover mixtures for temporary or permanent pasture, or on idle and waste land not now affording any profits and yearly becoming less valuable. The wider and more outspread the trials of the lespedeza, the greater is found the range of adaptability.

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HAPLOSPORANGIUM DECIPIENS THAXTER AND OTHER MICROFUNGI FROM ILLINOIS

BY

B. T. PALM

University of Illinois, Urbana.

During fields trips in the neighborhood of Urbana, Illinois, a number of interesting microfungi have recently been collected. As some of these seem to be of rare occurrence in the United States or seldom met with in Illinois, it has been thought expedient to put them on record in this short note.

HAPLOSPORANGIUM DECIPIENS Thaxter

On a sample of surface soil, containing considerable decaying algal material that consisted of *Vaucheria* sp. and various blue-greens, this *Haplosporangium* developed in the laboratory. The sample had been collected in Brownfield woods, near Urbana (November, 1930), in one of the temporarily dried-up creeks that run through the forest.

The fungus grew quite well in pure culture on corn-meal agar where it developed an abundant crop of the characteristic monosporial sporangia. The development of mycelium, sporangiophores and spores conforms very well with the original description and plates given by Thaxter (New or peculiar Zygomycetes. 3. Blakeslea, Dissophora, and Haplosporangium, nova genera, Bot. Gaz. 1914, vol. 58, pp. 353-366, see pages 364-365 and pl. 29, figs. 37-39). Zygospores are unknown, and all attempts to induce their formation by bringing together mycelial colonies of possibly different origin (all, however, from the original culture) were without results. There is thus some reason to believe that the material in cultivation belongs to a heterothallic strain.

The finding of this peculiar zygomycete in Illinois is well worth recording as it has so far, to my knowledge, been found only once. According to Thaxter (l.c p. 364) "it has been seen but once and was found on dung of the curious cave-dwelling Selenodon from Hayti". It is probably not so uncommon as it would seem from the records thus far published.

EVERHARTIA LIGNITALIS Thaxter

This helicosporoid fungus was found on decaying wood in Brownfield woods during the month of December, 1930. In spite of the temperature it had formed numerous sporodochia. The characteristics of the species agree well with the description of Linden in his monograph of the helicosporous Fungi Imperfecti (Ann. Missouri Bot. Gard. 1929. Vol. 16, pp. 227-388).

CLADOCHYTRIUM TENUE Nam.

This fungus is seldom recorded in literature but is probably not uncommon on decaying parts of higher water plants and algae. *Cl. tenue* was found in a sample of dying *Vaucheria* from Brownfield woods near Urbana.

Among parasitic fungi from Illinois worthy of recording are the following:

Peronospora floerkeae Kellerm. on *Floerkea proserpinacoides* Willd.; Brownfield woods (April, 1931).

Peronospora hydrophylli Waite on *Ellisia nyctelea* L., Oakwood (May, 1931).

Plasmopara obducens Schroet. on *Impatiens biflora* Walt.; Oakwood (May, 1931).

Entyloma floerkeae Holw. on *Floerkea proserpinacoides* Wild.; Brownfield woods (April, 1931).

ANTIPODALS IN ZINNIA

BY

B. T. PALM

University of Illinois, Urbana

The antipodal region in the female gametophyte of the Compositae has been extensively studied in recent years, and great variation has been found to occur with regard to its developmental history and final structure. As Schnarf has fully summarized our knowledge a few years ago (1929), the existing condition need be only briefly sketched here.

As a rule three uninucleated antipodal cells are initially formed in most of the Composites. Subsequent nuclear divisions may take place, generally accompanied by irregular wall formation. The number of resultant antipodal cells may be so high as to give rise to a so-called antipodal tissue. Equally, the number of nuclei in each individual antipodal cell may range from one to many.

In other cases only two antipodal cells are formed, the chalazal one inclosing one nucleus and the upper one two nuclei. The nuclear divisions that may occur in both cells, are seldom accompanied by wall formations. Thus only two antipodal cells, containing generally a great number of nuclei, will be present. Examples of this antipodal type are presented by several genera in the subfamily Heliantheae. A two-celled antipodal region has been described for example from *Bidens* (Dahlgren 1920), *Cosmos* and *Cosmidium* (Täckholm 1916), *Helianthus, Sanvitalia, Verbesina* and *Zinnia* (Hegelmaier 1889) and *Senecio* (Afzelius 1924).

It has been found that nuclear fusion often takes place between groups or between all of the nuclei present in such antipodal cells. Such fusions are said to be a more or less regular feature in the giant antipodal cells of *Cosmidium* (Täckholm 1916) and some *Senecios* (Afzelius 1924).

A chance inspection of some slides of the common garden *Zinnia* (*Z. grandiflora*) showed nuclear conditions in the antipodals of the embryosac which are of interest, adding as they do, a new variation to the many already observed in the *Heliantheae*. Incidentally, the antipodal development in *Zinnia grandiflora* gives a probable explanation of Hegelmaier's (1889) views regarding the origin of the female gametophyte in the Compositae.

Out of a row of four megaspores, the chalazal one gives rise to the embryosac. By the ordinary two successive nuclear divisions, two pairs of nuclei are formed in the developing young embryosac. All four nuclei then divide simultaneously. Of the resulting eight free nuclei, three constitute themselves into a perfectly normal egg apparatus; two of them give rise to the polar nuclei (fig. 1).

In the antipodal region the remaining three nuclei take up a linear arrangement. Between the uppermost of these antipodal nuclei and the lower polar nucleus a partition wall is laid down generally at right angles to the longitudinal direction of the embryosac. At the same time a second wall separates the two chalazal antipodal nuclei from each other, forming two antipodal cells with one nucleus each (fig. 1). No exceptions to this nuclear constitution were noted.

The subsequent behavior of the antipodal nuclei may proceed in two directions. In most cases seen, the two nuclei of the upper antipodal cells move to the centre of the cell where they fuse (figs. 5-8). Relatively rare is the occurrence of four nuclei in this cell; when four nuclei have arisen, fusion between at least two of the nuclei may take place (figs. 9, 10). Quite rarely the four nuclei remain separate (fig. 11) in old embryosacs (the age is indicated by the development of a massive endosperm structure).

The nucleus of the chalazal antipodal cell remains undivided; because of its small size this cell plays a correspondingly minor part in the antipodal system (figs. 2, 3, 4).

It is of interest not only that a fusion of antipodal nuclei occurs but that such fusion occurs with remarkable regularity. The nuclei, in preparation for the fusion, move to the center of the antipodal cell, as already indicated. Contrary to what could be expected, the fusion always seems to take place when the nuclei have moved to such a position in the cell that they lie side by side. Figures 5 to 9 illustrate their position in relation to each other and the main axis of the cell as well as some successive stages in the fusion processes. During the beginning stages of fusion one or both of the nuclei show changes in shape, being flattened or even of a somewhat amoeboid outline. The originally rather distinct nuclear membrane gradually looses its distinctiveness at the surface of contact between the nuclei (figs. 6 and 7). At the same time, there generally seems to occur a gradual augmentation in the number of nucleoli as well as in the intensity with which the chromatine takes the staining material. In figure 8 there remains barely a shallow double indentation, indicating that we have to do with a fusion product of two nuclei; the chromatin elements of both are

already completely united. The events described have generally taken place before the nuclei of the fertilized egg cell and primary endosperm show signs of division activity (fig. 4). No cases were observed from which it could be inferred that an antipodal fusion nucleus would divide later during the development of the endosperm.

Should the original two nuclei of the upper antipodal cell give rise to four nuclei, one pair of them may fuse, as indicated above, or all four may unite in one giant nucleus, if they do fuse at all. Figure 10 shows a case where the big lower nucleus is the result of a fusion; the small size of the upper two nuclei is due to the fact that their main bulk is to be found in another section. Figure 9 pictures the rare instance of a fusion of all four nuclei. Here the fusion product still shows in its outline the traces of the four participant nuclei.

The more or less constant fusion of the two nuclei in the upper antipodal and its occurrence at a rather early stage in the life history of the embryosac of Zinnia, in all probability explains Hegelmaier's error in interpreting the development of some Helianthoid embryosacs. According to Hegelmaier, the lower megaspore out of a row of four developes by consecutive nuclear division into a four nucleated embryosac. At each end of the embryosac the pair of nuclei were found. Thereupon the micropylar pair proceeds to form the egg apparatus plus the upper polar nucleus in the usual way. So far his account coincides with the normal sequence of development. With regard to the nuclei of the basal pair, however, he states that they do not undergo any further division but, after having separated, each of them forms an antipodal cell. The lower polar nucleus would thus be absent. He found this type of development characteristically enough in aberrant *Zinnia tenuiflora* and other members of the *Heliantheae* (see above) which, as we now know, constantly have two antipodal cells.

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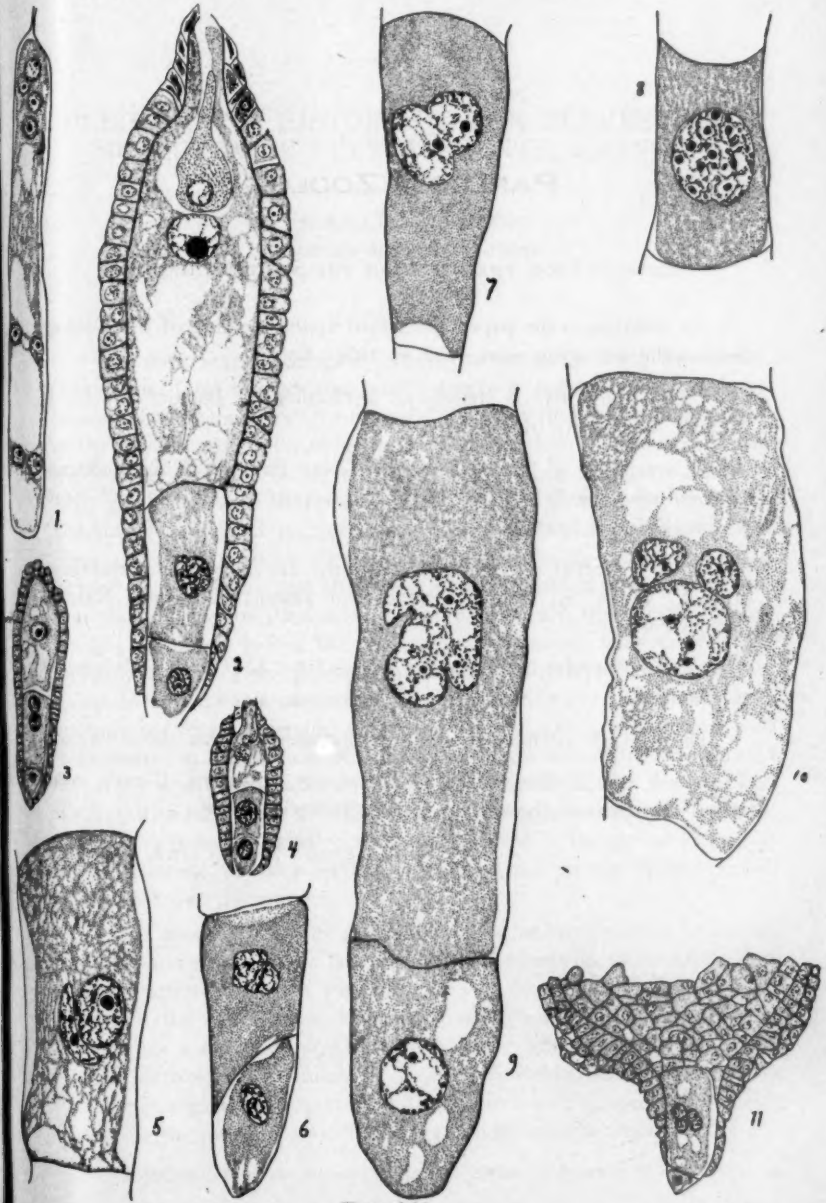
EXPLANATION OF FIGURES

ZINNIA GRANDIFLORA

FIG. 1. Eight free nuclei in the embryosac.
FIG. 2. Embryosac ready for fertilization.
FIGS. 3 and 4. Embryosacs with two antipodal cells, the upper one of which contains two resp. one nucleus.
FIG. 5. Early stages in the fusion of two antipodal nuclei from the embryosac shown in figure 2.
FIGS. 6 and 7. Consecutive stages in the fusion of two antipodal nuclei.
FIG. 8. Fusion nearly completed.
FIG. 9. Fusion product of four nuclei from the upper antipodal cell.
FIG. 10. Antipodal cell with three nuclei; the largest one formed by the fusion of two nuclei.
FIG. 11. Antipodal cell from old embryosac with four free nuclei.



FIGS. 1-11.

PAPERS IN ZOOLOGY

EXTRACT FROM THE REPORT OF THE SECTION CHAIRMAN

In addition to the papers presented at the meeting of the Zoology Section,the following were read by title only:

"The Mentality of Insects as an Ecological Factor," by C. L. Metcalf, University of Illinois.

"Correlation of Host Plant and Color Pattern of *Rhodobaenus tredecimpunctatus*," by Carl Mohr, University of Illinois and State Natural History Survey.

"An External Morphological Study of *Eremotylus macrurus* (Linn)," by A. R. Park, University of Illinois and State Natural History Survey.

"A New Species of Turtle for Illinois," by A. R. Cahn, University of Illinois.

The average attendance at the section meeting was about twenty.

Dr. F. C. Hottes, Millikin University, Decatur, Illinois, was elected chairman of the section for the following year.

(Signed) W. P. FLINT, *Chairman*

PLEISTOCENE HISTORY OF THE TERRESTRIAL MOLLUSCA OF FULTON COUNTY, ILLINOIS*

BY

FRANK COLLINS BAKER

University of Illinois, Urbana

INTRODUCTION

The most recent geological period, known as the Pleistocene, was characterized by the advance and retreat of several continental ice sheets. The phenomena attending the Glacial period are best developed in the Mississippi Valley, where all of the till sheets laid down by the ice may be studied in their relationship to one another. Between each glacial advance and retreat there was an interval during which the country returned to approximately its preglacial condition. It is obvious that as each ice sheet advanced it drove the fauna and flora before it or exterminated those species that could not escape. There was thus during the Pleistocene period a backward and forward swing of life, a retreat before the advancing ice and an advance into the devastated area after the ice had melted and the territory became favorable for the maintenance of life. In Illinois all of the interglacial periods are represented and all except the Aftonian (earliest) are well represented in Fulton County. Estimates of the time which has elapsed since the first glacial advance began have varied from a few hundred thousand to more than a million years. It is safe to estimate, perhaps, that not less than 500,000 years is represented in the period known as the Pleistocene, or some 400,000 years from the earliest Illinois period, the Kansan, to the present.

It is manifest that the fauna inhabiting an area subject to ice advances and retreats would be affected and the records, as far as they are known, attest that such was the case. It is surprising, however, to find that the effect upon the fauna has been so limited in the main, the larger number of species not differing greatly during this long period of time. The fauna as a whole, however, shows considerable change in regard to geographical distribution, several species now being found to the north or west of the area under consideration.

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*Contribution from the Museum of Natural History, University of Illinois, No. 66.

Fulton County is underlain wholly by Illinoian till, beyond the oldest Wisconsin moraine, the Shelbyville (fig. 1). Beneath this old till are numerous exposures of Yarmouth interglacial deposits. Singularly enough, not a record of Sangamon life is known from the county, although deposits of this interglacial interval have been noted to the southwest of Fulton County, mostly near or bordering Mississippi River. Peorian loess is noted rather abundantly in Fulton County as is also Early Wisconsin loess. Only one deposit referable to very early Late Wisconsin time has been noted, and this might well be placed in the Early Wisconsin series. In view of the recent disposition among physical geologists to consider the Iowan till as a member

Fig. 1. Map of a portion of the United States showing the extent of the several ice sheets of the Pleistocene period. It will be noted that Fulton County, represented by the black square, lies wholly within the area of Illinoian drift-sheet beneath which may be found the Kansan till-sheet. The Yarmouth interglacial deposits lie between these two drift-sheets.

of the great Wisconsin series, the Peorian, Early Wisconsin, and Late Wisconsin life is to be contrasted with the Yarmouth and with the recent life, a three-cornered comparison. What is known as Early Wisconsin, also, should probably be referred to some one of the subdivisions of the old Early Wisconsin, as the Shelbyville or Bloomington stages. The fossil beds found in this county and recorded as Late Wisconsin are not comparable to any found in the area behind the Valparaiso moraine, which are truly Late Wisconsin.

In the table are listed all of the species of land mollusks which have been recorded from Fulton County. The recent species are included mostly on the basis of the catalog by John Wolf, published in 1870 in the American Journal of Conchology, Volume VI, page 27, and modified and supplemented by the material in the museum of the University of Illinois. The fossil species are listed from the collec-

tions made in this county by Dr. Harold R. Wanless for the Illinois State Geological Survey and now in the University museum. The careful work of Dr. Wanless in collecting this fossil material has made it possible to make the comparisons of the variation of the molluscan faunas throughout the Pleistocene period in this county.

The Recent Fauna

The recent fauna is one of the most abundant yet found in the State, including 42 species of strictly land snails and two species of amphibious snails usually associated with land species. Comparing the recent fauna with the Pleistocene as a whole we note that it is especially rich in the larger helices (Polygyra and Anguispira) which are but poorly represented in the Pleistocene and become decreasingly abundant as we pass backward into this geological period. The smaller species, Gastrocopta, Vertigo, the zonitoids, etc., are relatively abundant in the Pleistocene as they are in the recent fauna. The absence of the larger land species in the northern and central part of Illinois during the Pleistocene period is also to be noted. As far as known at present the large Polygyras have been found only in Sangamon loess deposits at Alton. As far as species are concerned, the recent fauna contains 19 species not found in the Wisconsin series, 34 species not found in Peorian deposits, and 36 species not found in Yarmouth deposits. The recent fauna, therefore, is much richer in species at present than during any period of the Pleistocene. The Pleistocene faunas contain several species and varieties not now living in the recent fauna and some species represented by different varieties.

The absence of the larger snails from the fossil deposits, particularly the Peorian and Yarmouth, is especially noteworthy, indicating changes in environment or slight differences in average temperature. The loesses of the south, as at Natchez, Mississippi contain an abundance of the larger land snails, and this may be accounted for by the differences in climate between the two areas. The fauna, especially of the Yarmouth, at once suggests climatic and environmental features similar to those of northern Michigan and Minnesota at the present time. It is to be noted that several species of the smaller snails which are absent from Fulton County deposits are known from other parts of the state, but these are few in number and do not materially change the statements made for Fulton County. There are likewise several distinct species found in other parts of Illinois which have not been found is Fulton County, as *Gonyodiscus shimekii* and *Vertigo hannai*. But this discussion is restricted to the known distribution of the molluscan fauna in Fulton County.

The Pleistocene Fauna

As far as Fulton County is concerned, the Pleistocene fauna may be divided into three series, (1) the Wisconsin series, (2) the Peorian interval, (3) the Yarmouth interval. As would be expected, the

TABLE OF MOLLUSCAN DISTRIBUTION IN FULTON COUNTY

	Recent	L.Wis.	E.Wis.	Peo.	Sang.	Yarm.
Polygyra profunda						
albolabris						
multilineata						
m.wanlessi						
appressa						
elevata						
pennsylvanica						
thyroides						
clausa						
mitchelliana						
hirsuta						
h.yarmouthensis						
monodon						
m.fraterna						
Retinella electrina						
indentata						
wheatleyi						
Zonitoides arboreus						
Pseudovitrea minuscula						
Euconulus fulvus						
Haplotrema concavum						
Anguispira alternata						
kochi						
Conyodiscus c.anthonyi						
perspectivus						
macclintochi						
Helicodiscus paralellus						
Gastrocopta corticaria						
procera						
armifera						
contracta						
tappaniana						
pentodon						
Vertigo milium						
ovata						
tridentata						
modesta						
lossessensis						
gouldii,var.						
Pupilla muscorum						
Pupoides marginatus						
Columella edentula						
alticola						
Strobilops labyrinthica						
virgo						
Vallonia pulchella						
gracilicosta						
Succinea ovalis						
o.pleistocenica						
g.gelida						
avara						
retusa						
r.fultonensis						
Carychium exiguum						
s.canadense						
Hendersonia occulta						
Pomatiopsis lapidaria						
scalaris						
Fossaria parva						
p.tazewelliana						
Total species	44	25	19	24		20

Fig. 2

Wisconsin deposits contain a fauna only slightly different from the recent fauna. There is, however, an absence of the larger land snails.

The Wisconsin series contain 34 species, of which eleven species are not now found in the recent fauna. In other words, the recent fauna is about 23 per cent richer in species than the Wisconsin faunas. Of the eleven species not now living in Fulton County, seven are considered extinct or represented by different living varieties, and four live in other parts of the United States, three outside the limits of Illinois. Those not in the recent fauna are:

Polygyra multilineata wanlessi
Vertigo loessensis
Succinea ovalis pleistocenica
Succinea grosvenori gelida
Succinea retusa fultonensis
Pomatiopsis scalaris
Fossaria parva tazewelliana

Hendersonia occulta is almost extinct in Illinois, the records from Athens, Menard County, by Pilsbry and Moline, Rock Island County and Gallatin County by Shimek, being the only authentic ones from Illinois. Throughout the entire fossil record of the Pleistocene, from Yarmouth to Early Wisconsin, this species has been one of the most abundant members of the molluscan fauna. It is evidently approaching extinction and will finally disappear, as have some of the other Pleistocene species herein noted.

Vertigo modesta is a northern species whose range extends from Labrador westward to British Columbia and northward to Alaska. In the United States the typical form has been recorded from Maine, Vermont, and Connecticut. Various races are known from California, Utah, Idaho, Colorado, Nevada, Arizona, and New Mexico. It is, therefore, at present a western and northern species, far removed from Illinois where it was once common in the fauna. *Columella alticola* is now found in New Mexico, Arizona, Colorado, Wyoming, and northward into Alberta and other parts of British America. During Early Wisconsin time it was more or less abundant in Fulton County and other parts of Illinois. *Carychium exile canadense* is a common mollusk in northern Michigan and other parts of the northern United States and Canada. It has not been found in Illinois.

The fauna of the Peorian interval contains twenty-four species, of which eight are extinct or represented by other varieties and five live outside of Fulton County, and four outside of the state. The extinct forms are:

Polygyra multilineata wanlessi
Gonyodiscus macclintocki
Vertigo loessensis
Succinea ovalis pleistocenica

Succinea grosvenori gelida
Succinea retusa fultonensis
Pomatiopsis scalaris
Fossaria parva tazewelliana

Hendersonia occulta, Vertigo modesta, Carychium exile canadense, and *Columella alticola* have been commented upon above. *Vallonia gracilicosta* is a northern and western species, now living in Minnesota, western Iowa, South Dakota, Colorado, Arizona, and the Rocky Mountain region in general. It will thus be noted that only eleven species of the recent fauna are represented in the Peorian interval, thirteen being extinct or found in other parts of the state and nation.

The Yarmouth fauna is only about half that of the recent fauna or twenty species, of which nine are extinct, two are found outside of the state, and one outside of the county. Only eight species of the recent fauna are found in the Yarmouth interval in Fulton County. The extinct and changed forms are:

Polygyra multilineata wanlessi
Polygyra hirsuta yarmouthensis
Gonyodiscus macclintocki
Vertigo loessensis
Succinea ovalis pleistocenica
Succinea grosvenori gelida
Succinea retusa fultonensis
Pomatiopsis scalaris
Fossaria parva tazewelliana

Vertigo modesta, Vallonia gracilicosta, and *Hendersonia occulta* have been commented upon. *Vertigo gouldii* is a northern species found in the New England states southward to Alabama where it follows the mountains. It is common in Canada and has been found in the extreme northern part of Minnesota. The Yarmouth form of *V. gouldii* is somewhat different from the recent form of the species in the arrangement of the teeth and may prove to be a variety.

Summary

A study of the molluscan life of Fulton County during the Pleistocene geological period shows that the larger part of this period, from Yarmouth to Early Wisconsin time, the fauna consisted of a smaller number of species than is contained in the recent fauna and that a considerable percentage of the Pleistocene species were either different specifically or varietally or were of species now found to the north or west of Illinois. The earliest interglacial period recorded in Illinois, the Yarmouth, typically a forest covered area, is so different that of

twenty species recorded from the county, only eight species are the same as those living in this area today. A noteworthy feature is the absence of the larger species of Polygyra and the abundance of the smaller species during the early and middle part of the Pleistocene period. With the exception of a few examples of a form of *Polygyra profunda* found in concretions in strata supposed to be of Sangamon age, occurring at Alton, Madison County, Illinois, and a form called variety *wanlessi* of *Polygyra multilineata,* no large *Polygyra* has been found in any Yarmouth deposit in the state and more than forty different exposures are represented in the museum collections from Illinois. With few notable exceptions, this difference between the modern and Pleistocene fauna holds good throughout the entire state. Nine species and varieties are specifically or varietally extinct, five species do not now live in Illinois, and one species is known from but three localities in the state but is absent from Fulton County.

The present molluscan fauna of Fulton County is far richer in species than any fauna of the interglacial intervals, containing sixteen species not found in any of the Pleistocene series, excepting a few in the Late Wisconsin. The fauna is seen to gradually increase in number of species from the Yarmouth interval. A feature of special interest is that the greater number of the extinct and extralimital species persist until Early Wisconsin time, when they disappear from the fauna of the county.

CARNIVOROUS MOTHS AND BUTTERFLIES

BY

W. V. BALDUF

University of Illinois, Urbana

Moths and butterflies, because of their beauty and the ease with which their larvae may be reared, have long attracted much popular interest. We have a larger body of knowledge today concerning the members of this order than for any other group of insects. As a consequence, it has been conclusively established that the chief food of caterpillars is living plant tissue, but it is not so fully appreciated that large numbers of the Lepidoptera feed upon other animals, primarily other insects. The outstanding examples of carnivorous moths and butterflies now known occur in the tropical portions of the earth, but many exist in our own country. The habits of the carnivorous minority are characterized by a greater degree of specialization than is exhibited by their phytophagous relatives. A series of instances will serve to illustrate the nature of these habits.

A small number of cases has been recorded indicating that adult Lepidoptera may take the products of animals as food. Numerous moths, the most of which were Geometridae, were observed by Shannon [1] sucking the eye secretions of a horse in Argentina, and also visiting other parts of the body and endeavoring to feed on the perspiration. Their need for moisture is abundantly met by rainfall, hence it is considered more likely that the moths craved salt. Several observers in the tropics report seeing adult butterflies of the family Lycaenidae probing aphids and tree hoppers with their beaks to obtain the sweet secretion commonly produced by these Homoptera. The tropical hawk moth, *Acherontia atropos,* enters the nests of both wild and domesticated honey bees and with its relatively short beak sucks the honey from the cells. Although not carnivorous, these species have departed somewhat from the usual nectar sipping habit of their stage, and depend more or less on materials provided by other animals. In a similar way, the common clothes moths represent a divergent habit in the larval stage in their attack upon animal products. An African species, *Tinea vastella* Zell, is known to have constructed brown, fingerlike tubes of silk and debris on the horns of a dead water antelope. The tubes connect at the base with galleries in the horn, where the larvae feed. It

is considered possible that the tubes may occur also on the horns of the living animal.

Truly carnivorous Lepidoptera are invariably caterpillars, and may be divided into two groups, according to the regularity of their feeding habits, (1) occasional predators, and (2) habitual predators or parasites. Students of insects not infrequently observe a habitually phytophagous caterpillar turn carnivorous upon occasion. In control experiments, small codling worms in artificially infested apples become cannibalistic when the fruit is overpopulated. It is rare to find more than one corn earworm at a time on the tip of a corn ear, but when two or more occur, they are invariably distinctly separated from one another. The presence of a single larva on the ear is explained by the fact that the larger or more aggressive individual seizes the other and at least breaks the body wall of the victim, causing its death. This habit may simply indicate a pugnacious temper rather than a desire to feed, but it suggests one way in which carnivorous tendencies may begin. A similar viciousness exists in other common caterpillars, notably some species of Papilionidae and the monarch butterfly, but here the tendency has gone beyond the level of pugnacity. When plant food is inadequate these larvae attack their own kind, often individuals which have transformed to the pupa state, and consume them more or less entirely. Often the attack is limited only to what chances to be at hand. A tiger moth larva, ordinarily a plant eater, fed upon a noctuid caterpillar, and an Orthosid larva, placed in a cage as food for a predaceous Pentatomid, reversed the expected procedure and devoured the stink bug instead. *Heliothis dispaceus* seems [2] to eat the chrysalis of the imported cabbage butterfly *(Pieris rapae)* even when its food plant is available in the cage. However, in most instances of occasional predatism, the attack appears to be induced by hunger. Proximity, due to overpopulation or cage conditions, or factors sueh as a vicious nature, or the stimulus of hunger, or all of these in conjunction, may be responsible for this radical change in kind of food taken.

A small pryalid moth *Cryptoses choloepi* Dyar, possesses the remarkable habit of existing, perhaps in all its stages, in the fur of the living sloth. The gray pelt takes on a green color due to the presence of algae growing in large quantities on the hairs. Although the caterpillars may eat the algae, the insect is responsible for matting the fur, and we have the unique phenomenon of a phytophagous insect which, in a sense, owes its existence to a vertebrate host.

In the majority of carnivorous Lepidoptera, the practice of eating other insects has become mostly habitual. The handsome little pyralid moth, *Dicymolomia julianalis* Wlk., has been reared [3] from the bag

of the common bagworm. The larva is known to eat the eggs deposited in the bag in the fall by the wingless female moth. In each case, where a full grown larva was found, the eggs of the bagworm had been entirely consumed. The full-grown predator larva spins a cocoon on the outside of the free end of the bag. This species had been formerly reared from the heads of cat-tail. The adults probably issue in April or May, and the eggs of the bagworm hatch in spring, so that the progeny of the predaceous species must have another host to carry them through the summer.

Several moths belonging to widely separated taxonomic groups have become specialized to live at the expense of scale insects. Some of these may properly be designated as parasitic in habit, the entire larval life being spent within a single scale, but the larvae of other species crawl about and consume one coccid after the other. *Erastria scitula* Ramb. [4], a small Noctuid moth, deposits her eggs on leaves and young buds of plants infested with black olive scale and others, or directly upon the back of the bark-lice. The young larva at once enters its host, devouring all the internal organs, then seeks another scale, hastening to bury itself in the new victim. After ten days the larva begins to make a silk covering which enlarges the case previously formed of debris and the shells of consumed coccids. This case, which resembles smut-covered scales, is carried by the last instar larva. Openings are left for the head and venter. Under this armour, the predator crawls about devouring several scale insects each day. The case is finally enlarged, and when it has been attached to the bark of the tree, the larva spins a cocoon for pupation. Several generations occur in a year in Europe, all developing on scales.

Another Noctuid species, *Eublemma rubra* (Hampson), feeds on *Lecanium* scales in Central Java [7], and always carries a shield which is believed to protect the larva from the fierce red tree-ants, *Oecophylla smaragdina* which tend the scales. That the covering has a protective function is suggested also by the caution with which the larvae use it. As in the instance of *Erastria*, it is composed of pieces of scales intimately spun together, but remains open below. The basal rim of the shield is securely fastened by means of silk threads to the branch or leaf on which the caterpillar lives. When ready to move, the larva drags the shield a little forward, cuts off the anchoring threads, and at the same time fastening it again with new silk. In this way the shield is never loose from the branch and the caterpillar moves its house along slowly, until it comes upon a scale insect. If the prey is still young and flat, the shield has to be raised to get the victim partly underneath it, whereupon the insterstices between the lower rim of

the shield and the branch are closed with a dense web of silken threads. The caterpillar then gnaws a large hole in the back of the scale and devours its contents. The larvae of *Catoblemma sumbavensis* Hamp. carry a similar shield and destroy the Coccids, *Tachardia aurantiaca* Cock., which are also tended by the tree-ant.

The carnivorous habit of *Eublemma amabilis,* on the other hand, makes this species an enemy of man because it feeds extensively upon *Tachardia,* the lac insect, which is the source of the valuable commercial product known as shellac. In some tracts of India [8], 20 to 25 per cent of the lac scales are destroyed each year by this moth. The larva chews its way through the heavy covering of resin present over the lac insects and penetrates down into the lac cell. It devours both sexes of the scales, and makes galleries through the encrustation of scales as it goes. The insect pupates in these galleries. Two to three generations occur in a year. Several other species of noctuid moths also attack the lac insects in this way.

On the other hand a small pyralid, *Laetilia (Dakruma) coccidivora* Comst., a species widely distributed in the United States, does not form a portable case, yet like *Erastria* it consumes many scales during its larval growth. It feeds [5] on the eggs and young of our larger scales, *Dactylopius, Lecanium,* and the cottony maple scale, *Pulvinaria innumerabilis.* The larva works beneath the bodies of the scale insects [6], eating them out, one after another, from below. When the scales are crowded upon a twig or branch, the predator larva passes directly from one to the other without showing any indication of its presence but where the scales are more scattered and some distance intervenes between them, the *Laetilia* larva traverses the open spaces within a delicate silken tube which it spins as it goes.

If any carnivorous Lepidoptera may be said to be truly parasitic, this habit has been developed in the families Blastobasidae, and Heliodinidae. The prominent gall-like insects of the scale genus *Kermes* are the hosts of two species, the oak-coccid Blastobasid, *Zenodochium coccivorella,* and the more common Heliodinid *Kermes* parasite, *Euclemensia bassettella.* Comstock [5, p. 629] found the *Zenodochium* larva common as an internal parasite at Cedar Keys, Florida. *Euclemensia* is widely distributed in this country, being known from Connecticut, Florida, Minnesota, Texas, and intervening states. The larva makes its entire growth within a single individual of various *Kermes* species, and seems [9] to confine its activities to a V-shaped retreat or burrow which occupies the lower half of all the infested hosts, instead of working at large throughout the body of the scale. The larva, which is grub-like, possesses poorly developed thoracic and abdominal legs,

exhibiting the type of reduction of locomotor appendages and form of body generally associated with parasitic holometabolous insects. The full-grown larva cuts a small hole through the hard body wall of the host, and then closes it again with a thin, tough mesh of silken threads. The pupal stage is therefore passed within the shell of the host.

A unique instance of a small pyralid larva of the genus *Sthenauge* living as an external parasite on the caterpillar of several species of Saturniid moths of the group *Automeris* is reported [10] from Brazil. The parasite larvae spin a web across the back of the host caterpillar from spiracle to spiracle between two rows of spines, forming a loose transparent retreat open at each end. They eat the spines of the *Automeris* which sickens and finally succumbs. As many as six of these very active pyralid caterpillars may live on a single *Automeris* larva. The full-grown parasites pupate in a tough, blackish cocoon in the ground.

The tineoid family Epipyropidae includes a number of genera and species well known as parasites. These have become specialized to live at the expense of some members of the homopterous families Fulgoridae, Cicadellidae, or leaf-hoppers, and Cicadidae. Hawaiian entomologists contributed much of the present knowledge because the larvae are of economic benefit through their attack upon destructive leaf-hoppers, but reports of the interesting habits of these parasites have come also from South America and Australia. *Agamopsyche threnodes* is parasitic on the sugar cane leaf-hopper and allied hoppers in Hawaii. Perkins [11] gives a fairly complete life-history of this species, which is somewhat typical of the habits of other members reported in literature. The sluggish, parthenogenetic female begins oviposition very soon after emergence. The eggs are deposited in masses on dead grass leaves. The larval stage is passed on the back beneath the wings of either short winged or long winged adult hoppers. The larva, which has been aptly described as a "coccus-like insect," moults on the hopper's back, and in most instances the parasite has the head turned toward the tip of the abdomen of the host. Some Homoptera that serve as hosts of Epipyropidae excrete a mealy covering, which, it was sometimes believed, constitutes the food of the caterpillars. However, other hosts lack the waxy excretion. It is probable that the food consists of the honey-dew which is commonly produced by Homoptera affected by these larvae. The fact that the parasite's body is headed cauded suggests that this sweet liquid is taken as food. The effect of parasitism of this type on the host is not fully understood, but death not infrequently results, and usually the host's abdomen becomes shrunken and depressed.

According to observations of Dodd [12], the larva of the Queensland form *Epipyrops doddi* acquire a light, waxy, white cover, which is presumably a secretion of its own. Upon moulting, the entire white covering is shed, and a new one is formed in a few days. The larva is capable of dropping on a thread, as many caterpillars do, and when thus suspended, looks like a spider's egg case. The full-grown larva of known parasitic Epipyropidae leaves the hopper and makes a cocoon on grass blades.

Perhaps the most surprising examples of carnivorous Lepidoptera are to be found among the butterflies. Furthermore, all butterflies whose carnivorous habit is known to be habitual belong to the family Lycaenidae. In view of the delicate and beautiful forms of our native coppers and blues, one scarcely would have expected to find the aggressive and fine structural adaptations necessary to a predaceous habit, in the larvae of these butterflies. Yet, in this family occurs a relatively large number of species that eat other insects, and more remarkable still, the phenomenon of predatism has assumed a diversity of type exceeding that of any other groups of carnivorous Lepidoptera. However, the various exhibitions of this predatism are fundamentally related and probably derived from a common ancestral type of habit.

Of the eight subfamilies composing the Lycaenidae [15] only two, the Gerydinae and the Liphyrinae, so far as known are exclusively carnivorous, but the larvae of several others are carnivorous in the last instar.

The caterpillars of all the Lycaenidae are more or less slug-like, or for the most part shaped like sowbugs. Those of certain species are attended by ants. This attention [17] is due to the excretion by the larva of a liquid agreeable to the ants. The liquid is produced from a slit-like opening on the seventh abdominal segment. On the eighth segment is a pair of evaginable organs believed by some observers to yield an odor that serves to attract the ants. The larvae of some sixty-five species are reported to be attended by ants, and these organs have been found in a large number of species. However, not all ant-attended species are carnivorous.

A few examples will illustrate the trend of development of the lycaenid carnivorous habit and the bearing of association with ants and Homoptera upon that habit. Even among the phytophagous species, which predominate numerically in the family Lycaenidae, there exists a strong tendency toward occasional cannibalism.

The next step in lycaenid predatism is exemplified by *Lycaena alcon*. The young larvae [18] feed in the autumn on the flowers and other portions of *Gentiana pneumonantha*. When it reaches the third

instar it leaves the plant, and the rest of its development is completed in nests of ants. Here it feeds on both the larvae and the pupae of the ants. Other English species, *Lycaena arion*, and *L. euphemus* have similar life cycles, the last larval instar turning carnivorous upon ant brood.

Liphyra brassolis [15], an Australian species, places her eggs on the branches of a tree that bears several large nests of the tree ant, *Oecophylla smaragdina*. In this grade of predatism, the caterpillars, during all their growth, live in the nests of the ants and devour ant larvae. There is evidence that they pass from one domicile to another, presumably when their food is exhausted in one. They are evidently so tough skinned that the mandibles of the ants can make little or no impression upon them. Pupation takes place in the ant's nest, and the emerging adult, although attacked by the fierce ants, escapes unharmed. The scales covering the body of the butterfly adhere to the antennae and mandibles of the ant, so annoying the assailant that it retreats from the attack.

Lamborn [14] found *Aslauga lamborni* associated with *Cremastogaster buchneri* var. on a Euphorbiaceous plant bearing a scale, *Stictococcus sjöstedti* Cock., which are almost invariably attended by ants. In this animal complex, the Lycaenid larvae consumed the Coccidae. No dorsal gland was found on them. Their skin was hard, tough, and covered with coarse, rough tubercles, evidently protective in function, and it extended down as a fold on all sides in carapace fashion so as to protect the soft lateral and ventral surfaces. The lower margin of this fold bore a fringe of very fine hairs such as would efficiently prevent small insects from crawling underneath. Only the presence of spiracles gave evidence of body segmentation. On account of the long neck, the larva is able to thrust the head out and retract it in a tortoise-like manner. Such a protective covering suggests hostility from the ants, and the absence of the honey-dew gland indicates that the ants have no incentive to be on friendly terms with the caterpillars that destroy their food-producing coccids. A special development in method of attack for the sake of securing food is shown by the African *Megalopalpus zyma* [14]. The associated ant was *Pheidole aurivillii* which attends certain leaf-hoppers and tree hoppers. Again, the ants obtain no food from the Lycaenid larva, which, like the one described above, is equipped with a hard, defensive skin, and in addition is studded with tubercles surmounted with coarse hairs. The caterpillar has the ability to capture the Homoptera. The larva was often seen crawling slowly in the direction of the leaf hopper, *Nehela ornata*, stopping frequently and vibrating all three pairs of thoracic legs. Upon reaching the hopper,

the caterpillar caused its vibrating legs to play on the closed wings of the prey, in such a way, so Lamborn thought, as to simulate the caresses of the usual attending ants. Still advancing, it gradually raised the fore-part of its body so as to overhang the insect, and, when well above it, suddenly dropped and seized its prey with all its legs, immediately devouring the victim. Our own *Feniseca tarquinius* exhibits a similar relation to ant-tended Homoptera. This species, like many other Lycaenidae, seems to occur rather locally, being present only in the neighborhood of water where alder grows. However, it is widely distributed in the eastern half of the United States and Canada [15]. It appears to have three to five generations in a year from the northern to the southern limits of its range in the United States. The female usually deposits her eggs in the mass of aphids infesting the alder. There may be a dozen or more in a single colony of plant lice. Most often the alder aphis, *Schizoneura tessellata,* has been found to be the food of this caterpillar, but other plant lice are known to be consumed by them. The exact place of pupation has not been satisfactorily determined. Clark feels sure that the mature caterpillar drops to the ground to pupate on any convenient support.

Perhaps the most specialized food habit among Lycaenidae is that of *Euliphyra mirifica* Holl., another African form, associated with the ant, *Oecophylla smaragdina* var., which weaves leaves together composing its tent. The larvae of *Euliphyra* live in the nests of *Oecophylla.* Lamborn [14] observed this caterpillar thrust its little proboscis into the jaws of a large ant and keep it there while the ant made movements as if feeding it. Sometimes, when a large ant was feeding a smaller one, the latter retired in favor of a caterpillar waiting with proboscis extended to be fed. These caterpillars have neither dorsal gland nor tubercles, and it has not been discovered how they can benefit the ants. In fact, the larva is sometimes assailed by the ants, but its hard, carapace-like shield is at once drawn down to the supporting surface, effectively protecting the caterpillar.

Clark [15] summarizes the evolution of the food habits of carnivorous lycaenid larvae, saying that they are merely an extension of the intimate association with ants. This association is eminently characteristic of the carnivorous Lycaenidae, for they all feed either upon the brood of ants, upon material regurgitated by ants, or upon ant-tended insects. From the habit of feeding on ants or on ant-tended insects there is the natural transition, seen in *Euliphyra,* into a form which induces ants to feed it.

Some of the Lycaenidae in the warmer latitudes of our country may prove to have interesting carnivorous habits. A study of such

species would perhaps reveal additional intermediate steps showing the nature of the transition from the phytophagous to the carnivorous habit of feeding in this family. Some light could perhaps also be thrown on the origin of predatism as a phenomenon by a study of the conditions that induce normally plant-eating caterpillars to turn cannibal or predator on some occasions. Any attempt to answer these questions by an extensive investigation should yield much interesting information as well as keen enjoyment.

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OBSERVATIONS ON THE LIFE HISTORY OF A FINGERNAIL SHELL OF THE GENUS SPHAERIUM

BY

T. DALE FOSTER

University of Illinois, Urbana

ABSTRACT

Very little work has been done on the life history of the fingernail shells. Most of the conchologists interested in the bivalves have confined their work to the larger pearly fresh-water mussels about which much information has been published. The studies that have been made on the fingernail shells have been, for the most part, taxonomic in character. Those comparatively few which are not taxonomic are chiefly morphological.

This study, suggested by Dr. H. J. Van Cleave of the University of Illinois, focuses attention on the life history and reproductive habits of the Sphaeriidae. The material studied was taken from a small ox-bow pond near Muncie, Illinois, in a series of monthly quantitative collections beginning in February of 1930 and extending throughout the year to and including March of 1931.

The conclusions were founded on a statistical analysis and microscopical examination of these collections. From the data obtained by this method of approach, an attempt has been made to interpret the life history and reproductive habits of *Sphaerium solidulum*, one of the numerous species of genus Sphaerium, a widely distributed animal group of North America.

Observations made and conclusions formed as a result of this study are summarized as follows:

1. Twelve monthly quantitative collections made from the same habitat gave 7,022 individuals, or an average monthly collection of 585 individuals of the same species (*Sphaerium solidulum*).
2. Distribution curves were prepared based upon numbers of individuals falling into eighteen size-groups depending upon the thickness of the animal.
3. Correlation of size groups with material taken from different habitats was noted.

4. No individuals of maximum size were present during the months from August to February.
5. Individuals of the species under observation have a distinctly limited life span of approximately one year.
6. The analysis of distribution curves of each quantitative sample indicates two size-groups in each collection as shown by the bimodal character of each graph.
7. The maximum period of reproduction of this species does not occur in the summer months as previously believed but in the winter months.
8. Seasonal growth rings are not present on this shell although concentric lines are characteristic.
9. Anatomical investigation of marsupial pouches of the December and July adults reveals:
   (a) Marsupial pouches generally contain either two or four embryos.
   (b) When four embryos occur, two are distinctly larger than the other two.
   (c) Embryos are found in individuals of size groups that have attained one half maximum adult size.
   (d) A larger percentage of "young" adults appears in December than in July.
   (e) Distribution curves of embryos feature the bimodal character of the young and adult.
10. Maximum size adults are apparently sterile.
11. Clasping habits of the young when disturbed may be a factor in the distribution of the species.

USE OF TEMPERATURE ACCUMULATIONS AS AN INDEX TO THE TIME OF APPEARANCE OF CERTAIN INSECT PESTS DURING THE SEASON

BY

P. A. GLENN

State Department of Agriculture,
Division of Plant Industry,
Urbana, Illinois.

It has long been a matter of common observation that insects are very sensitive to temperature. As the cold of winter approaches many perish, and others go into hibernation to await the warmth of spring. In the spring they are aroused from hibernation and pursue their normal course of feeding, reproducing, and developing when the temperature rises to about 50° F., becoming more active as the season advances and the temperature rises until it reaches the optimum temperature for development in midsummer, when the rate of development is at its highest point. Above this point the torrid heat of summer is unfavorable for development of some species, resulting in the slowing up of their activities and development. As the temperature rises still higher, many go into estivation and others succumb to the intense heat.

In recent years many investigations have been conducted to determine more definitely the relation between temperature and rate of development in insects. The writer in 1915-16-17 collected data on the development of the stages of the codling moth, the life history, and the progress of the seasonal history, and sought to relate the temperature to rate of development and the accumulation of temperature units to progress of development, using out-of-doors temperatures in making the correlation.

The purpose of this paper is to explain briefly how temperature units may be used to forecast the date when any stage of an insect pest may be expected to appear, and to do so long enough in advance of its appearance to enable the grower of crops to take proper steps to ward off threatened injury.

In this latitude, temperatures range from about —30° to about 115° F. The range between these extremes may be divided into six zones, based on the reaction of insects to different degrees of temperature, as indicated below.

6. High Fatal Zone.....	Fatality due to heat.
5. Estivating Zone.....	Not fatal, but unfavorable for development.
4. Retarding Temperature Zone.	Rate of development decreasing with rise of temperature.
Temperature of maximum rate of development.	
3. Effective Temperature Zone.	Rate of development increasing with rise of temperature.
Zero of development.	
2. Hibernating Zone.....	Not favorable for development due to lack of heat.
1. Low Fatal Zone.....	Fatality due to lack of heat.

In these studies we are interested in the zones of effective temperature and retarding temperature, the relation of different temperatures to the development of the different stages and to seasonal development of insects.

Studies of the codling moth revealed that the rate of development in all its stages varied almost directly as the rise and fall of temperature within the zone of effective temperatures. Other investigators, by the use of apparatus for controlling temperature and humidity, have ascertained that changes in temperature near the zero of development have a slightly less value in producing change in rate of development and that similar changes in temperature near the upper part of the zone of effective temperatures have a slightly greater value, than do like changes in temperatures near the middle of the zone. They also have determined that humidity has a slight effect on the rate of development and on the zero of development, but these can not be detected by the use of varying out-of-door temperatures and it is unnecessary to take account of them for practical purposes. In these studies, therefore we are assuming that within the effective temperature zone the rate of development varies as the temperature.

It was also found that when the temperature rises above the point at which the maximum rate of development is reached, the rate of development was retarded approximately as it would be if the temperature had fallen a like amount below that point, and although this may not be quite accurate, it is assumed to be sufficiently accurate for our purpose. This relation enables us to convert retarding temperatures into equivalent effective temperatures, as the rate of development at two, three, or four degrees above the temperature of the maximum

rate of development is approximately the same as at a temperature of two, three, or four degrees below that point. If, for instance, the temperature of the maximum rate of development of the pupa of the codling moth is 87° F., the rate of development of the pupa would be approximately the same at 90° F. as it would be at 84° F.

The limiting point between the hibernating zone and the effective temperature zone is called the zero of development. It is the temperature at which development ceases when the temperature falls and at which development begins when the temperature rises from hibernating temperatures.

The limiting temperature between the effective temperature zone and the retarding temperature zone is the temperature at which development proceeds at its highest rate.

These two points may differ for different insects and for different stages of the same insect.

The limits of the various zones have not been determined definitely for any insect, but the zero of development is in the neighborhood of 50° F. and the temperature of the maximum rate of development is probably between 85° and 90° F.

For the codling moth the zero of development for the larva and egg is near 50° F. and for the pupa 52° F.; the degree of the maximum rate of development for the egg, larva. and pupa respectively is near 88°, 85°, and 87° F.

The units of temperature accumulation used in this investigation are the day-degree and the effective day-degree. A day-degree is a unit of one degree operating for one day. An effective day-degree, or a day-degree of effective temperature, is a day-degree measured by temperatures within the effective temperature zone.

The day-degrees which accumulate above any temperature used as the zero for any day are the same as the average of the hourly temperatures above that zero.

To compute the effective day-degrees for any day during which the temperature does not at any time rise above the temperature of the maximum rate of development, add the hourly temperature readings for the day above the zero of development, and divide by 24, or add the hourly readings for each alternate hour and divide by 12.

To compute the effective day-degrees which accumulate during a day when the temperature for part of the time is above the temperature of the maximum rate of development, subtract from the average day-degrees above the zero of development, twice the average day-degrees above the degree of the maximum rate of development. The

result will be the day-degrees of effective temperatures, or the number of effective day-degrees which accumulated during the day, and will serve as a quite accurate index to the value of the day in furthering the development of any stage of the insect or its life, or seasonal history.

The formula for the effective day-degree accumulations for any day may be written, $x = a - 2b$, in which "a" is the average of the hourly temperatures for the day above the zero of development, and "b" is the average of the hourly temperatures for the day above the degree of the maximum rate of development.

The following table illustrates the relation of temperature to the incubation period of the codling moth, the zero development being 50° F. and the degree of maximum rate of development 88° F.

TABLE I.

TEMPERATURE AND THE INCUBATION PERIOD OF THE CODLING MOTH

No. Obs.	Period in Days p	Mean Daily Tem. deg. F.	Average daily day-degrees			Total day-degrees	
			(50+) a	2(88+) 2b	(50+)−2(88+) a−2b	50+ ap	(50+)−2(88+) (a−2b)p
46	14.00	61.60	12.30		12.30	172	172
229	12.67	63.11	13.31		13.31	170	170
622	10.66	64.94	15.13		15.13	161	161
305	9.35	67.48	17.47		17.47	163	163
595	8.67	69.01	19.01		19.01	165	165
515	7.72	71.33	21.33		21.33	165	165
572	7.00	73.12	23.12	.01	23.11	162	162
335	6.60	74.86	24.86	.45	24.41	164	161
232	6.02	77.43	27.43	.96	26.47	165	159
249	5.95	78.71	28.71	.96	27.25	171	165
288	5.71	80.14	30.14	1.93	28.21	172	161
141	5.52	82.86	32.86	3.74	29.12	181	161
46	5.53	84.00	34.00	4.66	29.34	188	162
4175	7.67		21.70		21.33	166	163

Column 4 gives the average day degrees above 50° F. for the period (a); column 5 gives twice the average daily day-degrees above 88° F. (2b); and column 6 gives the remainders left after subtracting the retarding day-degrees in column 5 from the corresponding day-degrees in column 4, or the average daily effective day-degrees for the period (a—2b).

The periods (p) are given in column 2. Column 7 gives the products of corresponding numbers in columns 2 and 4, or the total day-degrees which accumulated above 50° F. during the period at the various temperatures (ap). Notice the wide variation in the numbers in

column 7, and that the last four numbers in column 7 increase above the average at the higher temperatures. This is due to the fact that column 4 includes some retarding day-degrees.

Column 8 records the products of the corresponding numbers in columns 2 and 6, or the average effective day-degrees which accumulated during the incubation period at the different temperatures (a—2b) p. The difference between columns 7 and 8 is that the proper corrections were made in 8 for retarding temperatures above 88° F. whereas no correction was made in computing column 7.

The formula for the incubation period may be given as (a—2b) p= c=163, in which "c" is the average total number of effective day-degrees which accumulates during the period, or the so-called thermal constant for the period. It will be noticed that the variation from the average number of accumulated day-degrees at the different temperatures is very slight.

A practical application of the relation disclosed in Table 1 may be illustrated as follows:

It was observed that the first adults of the codling moths were emerging in an orchard May 11, 1915, at Olney. We did not know it then, but it is now known that about 50 effective day-degrees accumulate before egg-laying begins, and that 163 more accumulate before the eggs hatch, and that the average daily accumulation of effective day-degrees at Olney at that time in the season is 15. Therefore, by solving the simple problem, (50 + 163) ÷15 =14, we might have determined that 14 days after May 11, or May 25, the first larvae would be hatching in the orchard. With this information, the orchardman could have had 14 days in which to plan to have the first cover spray on his trees by May 25. In this particular instance the first larvae were observed to be hatching on May 25. We can not always expect to forecast the date that closely. If the weather during the period should be colder or warmer than normal, the date of hatching would be delayed or hastened a day or two, but if the weather is normal, the predicted date will usually coincide with the actual date.

For the last few years the information furnished to the orchardmen of Illinois each spring by Mr. W. P. Flint of the Natural History Survey Division as to the time when the first cover spray for the codling moth should be applied, has been obtained by this method, and has proved very useful and accurate.

The following table illustrates the relation of temperature to the larval period of the codling moth, the zero of development being at 50° F. and the maximum rate of development at 85° F.

TABLE II.

TEMPERATURE AND THE LARVAL PERIOD OF THE CODLING MOTH

No. Larvae	Periods in Days p	Mean Daily Temp.	Daily day-degrees			Total Day-degrees	
			50+ a	2(85+) 2b	(50+)-2(85+) a-2b	50+ ap	(50+)-2(85+) (a-2b)p
22	35.57	69.45	19.45	.34	19.11	692	680
122	32.29	70.88	20.88	.30	20.58	674	665
45	29.20	73.48	23.48	.72	22.76	686	665
33	28.62	74.53	24.53	.74	23.79	702	681
14	27.14	76.74	26.74	1.40	25.34	726	688
20	25.93	79.39	29.39	3.62	25.77	762	668
78	26.33	80.30	30.30	4.36	25.94	798	683
344	29.07	74.31	24.31	1.56	22.75	719	673

The same method was followed in analyzing the data on the larval period. The approximate zero of development was found to be 50° F. and maximum development was found to occur at 85° F. Column 4 gives the average daily day-degrees above 50° F. (a); column 5 gives twice the number of day-degrees above 85° F. which must be subtracted from day-degrees in column 4 to make correction for the retarding temperatures above 85° F. (2b); and column 6 gives the corrected day-degrees above 50° or the average daily effective day-degrees for the period (a—2b). Columns 7 and 8 are the products respectively of columns 2 and 4 (ap) and columns 2 and 6 ([a—2b]p). The total day-degrees shown in column 8 are quite uniform in number for different temperatures. The variations are greater than the totals in the corresponding column of Table I, but the larval period is much longer than the incubation period, and there is a correspondingly greater variation in the larval periods than in the incubation periods, and also the number of larvae under observation was much smaller than the number of eggs.

The formula for the average larval period for larvae reared in apples on the tree may be written: $(a—2b)p = c = 673$. It is interesting to note in this connection that the formula for the larval period for larvae reared in picked apples, based on the rearing of 214 larvae, is $(a—2b)p = c = 587$, of 86 day-degrees less than for larvae reared in apples on the tree, showing that the character of the food materially affects the rate of development. A difference of 86 effective day-degrees in the total is equivalent to a difference of about 4 days in the length of the period.

Table III shows the relation of temperature to the pupal period of the codling moth, the zero of development being at 50° F. and 52° F. and the maximum rate of development at 87° F.

TABLE III

PUPAL PERIOD OF THE CODLING MOTH

Summary on Relation of Temperature to Development

No. of observations	Periods in days p	Average mean daily temperatures	Average daily day-degrees					Total day-degrees			
			50+ a	52+ a′	2(87+) 2b	(50+)—2(87+) a—2b	(52+)—2(87+) a′—2b	50+ a′p	52+ a′p	(50+)—2(87+) (a′—2b)p	(52+)—2(87+) (a′—2b)p
2	45.50	52.60	6.19	5.19	.....	6.19	5.19	281.6	236.0	281.6	236.0
348	35.20	55.70	7.85	6.80	.....	7.85	6.80	276.3	237.9	276.3	237.9
976	34.01	56.15	8.24	7.08	.....	8.24	7.08	280.2	240.8	280.2	240.8
243	27.77	58.50	9.92	8.69	.....	9.92	8.69	275.5	241.3	275.5	241.3
218	13.80	69.28	19.27	17.31	.....	19.27	17.31	265.9	238.9	265.9	238.9
175	12.70	70.79	20.79	18.79	.04	20.75	18.75	264.0	238.6	263.5	238.1
221	11.51	73.11	23.11	21.11	.24	22.87	20.87	266.0	242.8	263.2	240.2
247	10.73	74.92	24.92	22.92	.42	24.50	22.50	267.4	245.9	262.9	241.4
517	10.02	76.77	26.77	24.77	.88	25.89	23.89	268.2	248.2	259.4	239.4
481	9.44	79.14	29.13	27.13	1.63	27.50	25.50	275.0	256.1	259.6	240.7
133	9.43	80.88	30.88	28.88	3.52	27.36	25.36	291.1	272.2	257.9	239.0
256	9.24	82.68	32.68	30.68	4.12	28.56	26.56	302.0	283.5	263.9	245.4
3817	14.49	.....	19.03	17.38	.77	18.26	16.61	275.6	251.8	264.6	240.7

The same method was followed in analyzing the data on the pupal period as on the incubation and the larval period, except that the results obtained by using both 50° F. and 52° F. as the zero of development are included in this table. The degree of the maximum rate of development for the pupa was determined to be approximately 87° F. Column 11, [(a—2b) p] shows the total effective day-degrees above 50° F. after corrections have been made for temperatures higher than 87° F. and column 12 [(a′—2b) p] shows the same above 52° F.

The fact that in column 11 the total effective day-degrees are much higher at the lower temperatures than at the higher temperatures indicates that 50° F. is below the true zero of development; and the fact that the total effective day-degrees in column 12 are quite uniform in number for all temperatures indicates that 52° F. is near the true zero of development. However, the error will not be great if 50° F. is used as the zero, and as it is much more convenient to use the same zero for the pupa as for the larva and the egg, 50° F. is used in all the computations made. The formula used, therefore, is (a—2b) p= c = 265.

By the use of this table and some simple observations one may forecast very accurately when the first larvae of the second generation of the codling moth will begin to hatch in his orchard. In order to make the observations, the orchardman should put some bands on a number of trees in his orchard, or, preferably, some isolated trees which may be left unsprayed. These bands should be examined daily beginning June 1, until the first larvae are found under them. Then a computation of this kind can be made:

$$3 + \frac{265}{d} + \frac{50 + 162}{d} =$$

number of days, after first larvae are found under bands until the first larvae of the second generation will be hatched in the orchard. The "3" in the above statement represents the days that usually elapse before the larvae change to pupae after entering the bands; "d" represents the average daily accumulation of effective day-degrees that normally accumulate during the three weeks following the date when the first larvae are found, and its value may be estimated by reference to the fourth column of Table No. V; 265 is the average number of effective day-degrees that accumulates from the date of pupation to the date of emergence; and $\frac{50 + 162}{d}$ is the average number of days that elapse between the emergence of the moths and the hatching of the young larvae.

Suppose at Urbana the first larvae of the first generation were found under the band June 20. We would proceed as follows to ascertain when to expect the larvae of the second generation to hatch in the orchard. We would first refer to Table V, ascertaining the value of "d" during the three weeks following June 20 to be 23.

$$3 \text{ days (days until larvae will pupate)} + \frac{265}{23} \text{ (days until moths will emerge)} + \frac{50 + 163}{23} \text{ (days till eggs will hatch)} = 24$$

Twenty-four days after June 20 is July 14. The orchardman would in this case have twenty-four days in which to plan to have the first spray on his trees for the second brood of worms.

This method also has been employed by Mr. Flint in preparing the forecasts sent out to orchardmen as to time to apply the first spray for the second brood of the codling moth.

As mentioned above, the egg, larva, and pupa of the codling moth react somewhat differently to temperature, 50° F. being the approximate zero of development of the egg and the larva, and 52° F. the zero for the pupa, while 88°, 85°, and 87° F. are the approximate temperatures at which the egg, larva, and pupa develop most rapidly. However, if we wish to apply the temperature relations to the whole development period and to the seasonal history, we shall have to select one zero and one degree of the maximum rate of development for all three stages. The most satisfactory zero for all three stages is 50° F. and for the degree of the maximum rate of development 86° F. Table IV gives the results obtained by applying them to the development period which covers the period from the deposition of the egg until the emergence of the adult.

TABLE IV

RELATION OF TEMPERATURE TO THE DEVELOPMENT PERIOD OF THE CODLING MOTH

Generation	Number of observations	Year	Average period	Av. daily effective day degrees	Total effective day degrees
First	74	1915	53.4	21.18	1131
First	65	1916	52.4	21.53	1128
First	104	1917	50.3	22.09	1111
Second	13	1915	49.	22.49	1102
Second	92	1916.	44.1	25.35	1118
	348	....	49.34	22.35	1118

Although 1118 was the average number of effective day-degrees which accumulated during the development period, the number of such units which accumulated during the period of individuals within the group varied widely.

The lowest temperature accumulation during this period for any of the individual females was 880 day-degrees but less than 4 per cent of the individuals had accumulations below 950 day-degrees. This latter number may be considered the approximate minimum. As the development period does not include the period which elapses between the time when the adult emerges and the time when she begins to deposit eggs, allow 50 effective day-degrees to cover this time, making in round numbers 1000 as the minimum number of effective day-degrees which accumulate during the entire life cycle from egg to egg. We may therefore expect a new generation of the codling moth for every accumulation of 1000 effective day-degrees that is completed. Observations have corroborated the approximate accuracy of this conclusion.

Thus far the relation of temperature to the egg, larva, pupa, and development periods of the codling moth have been shown, and a method of forecasting the dates when the first larvae of the first generation and the first larvae of the second generation may be expected to appear, by the use of certain observations made in the orchard and the application of the ascertained temperature relations. There is also a relation between temperature and the seasonal history of the codling moth, and time of the appearance of the first individuals of any brood of eggs, larvae, or moths, may be anticipated, even in the absence of definite observations.

To be able to follow the seasonal history of the insect by the use of accumulated temperature units only, it will be necessary to keep a daily record of the effective day-degrees that accumulate, and the total effective day-degrees that have accumulated from the beginning of the season.

By the use of a self-recording thermometer it is a simple matter to compute and record the effective day-degrees above 50°F. that accumulate daily, using the formula, $x = (a - 2b)$, in which "a" represents the average of the hourly readings above 50°F. and "b" represents the average hourly readings above 86°F. Then the total number of effective day-degrees which has accumulated from the beginning of the season up to and including each date may be obtained by adding the accumulation for each day as it is computed to the total accumulation recorded for the preceding day.

When the total accumulation of effective day-degrees approaches 340, one may expect the first adults of the codling moth to be emerging from the overwintering larvae; and when it reaches 550, one may expect the first larvae to be entering the fruit. When it approaches 1342, the first moths of the second brood may be expected to emerge, and when it approaches 1550, the first larvae of the second brood may be expected to hatch in the orchard. In like manner the first adults of the third brood of moths will appear about the time when the sum of effective day-degrees reaches 2342, and the first larvae of the third brood when the sum reaches 2550.

To illustrate a little more clearly the significance of accumulated day-degrees of effective temperature, Table No. V has been prepared, showing the total accumulations from the beginning of the season at Urbana, Illinois, for each day from May 1 to August 31, for the years 1921, 1929, and 1924, also the average daily accumulations and the average total accumulations for each day for the same period, at Urbana, based on 14 years records.

The numbers representing the total effective day-degrees in columns 1, 2, and 3 reflect fairly accurately the advancement in the seasonal history of the codling moth during the years 1921, 1929, and 1924, and the numbers in column 5 show the progress of the seasonal history of the insect in a normal year at Urbana.

If the large differences in the numbers in the horizontal lines after any date for the three years and the average at Urbana are noted, it will be seen how much the seasonal history may vary in different years.

If, for instance, we wish to know how great a variation occurred in 1921, 1929, and 1924, in the dates when the first larvae of the first generation of the codling moth began to hatch in the orchard, we will find in each column the number nearest to 550, and we shall see that the first larvae hatched in 1921 about May 22 or 23; in 1929, May 29 or 30; and in 1924, June 14, and that the normal date at Urbana is June 1. There was a difference of seven days between 1921 and 1929, 16 days between 1929 and 1924, and an extreme difference of 23 days between 1921 and 1924.

Similarly, we might learn something of the variation in dates of the hatching of the first larvae of the second generation in different years by observing the dates on which the accumulations of day-degrees of effective temperature were near 1550. This event occurred theoretically on July 2 or 3 in 1921, July 19 or 20 in 1929, on August 1 in 1924, and it occurs normally on July 19, at Urbana.

The larvae of the third generation began to hatch theoretically on August 11 in 1921, September 5 in 1929, October 4 in 1924; and it begins normally on September 1 or 2 at Urbana.

Column 4 gives the day-degrees of effective temperature which normally accumulate daily at Urbana. It is desirable to know the normal daily accumulations and the total accumulations during the season up to and including each day of the year for a number of localities in the State and the nation, such as are given for Urbana in the last two columns of Table V.

Having this information, one will be able to compute the date when a certain event in the seasonal history of an important insect will occur at one place if the date when it occurred at another place is known.

It will be seen that there are many ways in which a knowledge of the significance of day-degrees of effective temperature and their accumulation as the season progresses can be of use to the practical orchardman or to the entomologist, especially in enabling him to forecast the dates when larvae of the several generations will begin to hatch, and when hatching will be at its height.

The accumulated day-degrees alone may be depended upon in forecasting the date when the sprays should be applied, or they may be used in connection with observations as illustrated earlier in the paper, as they have been used in Illinois for the last few years in forecasting the dates when sprays should be applied for the first larvae of the different broods.

It is of interest to note how accurately an event may be forecast by the use of accumulated day-degrees of effective temperature. While data were being collected for this study at Olney, Illinois, in 1915, 1916, and 1917, accurate observations were made on the dates when the first larvae of the three generations hatched as compared with the forecast or theoretical dates when they should have hatched.

Observations at Olney

Generation	Year	Theoretic date	Observed date	Difference in days
First	1915	May 15	May 17	2
First	1916	May 24	May 25	1
First	1917	May 31	June 2	2
Second	1915	July 11	July 11	0
Second	1916	July 10 or 11	July 11	1
Second	1917	July 18	July 17	1
Third	1915	Aug. 23	Aug. 29	6
Third	1916	Aug. 18	Aug. 20	2

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Observations at Urbana

Generation	Stage	Year	Theoretic date	Observed date	Difference in days
Hibernating	1st adult	1924	May 28	May 30	2
Hibernating	1st adult	1925	May 6	May 9	3
First	1st larvae	1926	June 6	June 3–5	1 to 3
First	1st adult	1926	July 15	July 9	6
First	1st adult	1927	July 13	July 15	2
Hibernating	1st adult	1928	May 16	May 20	4
First	1st adult	1928	July 11 or 12	July 13	1 or 2
Hibernating	1st adult	1929	May 12	May 12	0
First	1st larvae under band	1929	June 24	June 26	2
Hibernating	1st adult	1930	May 4	May 5	1

The differences between the predicted, or theoretic dates, based on accumulated day-degrees of effective temperature and the actual dates on which the events were observed to occur are remarkably small, and as observations may not always be accurate, especially if they are not made systematically, the discrepancies above recorded may be more the result of faulty observations than of methods of determining the theoretic dates.

Dr. T. J. Headlee, State Entomologist of New Jersey, in his report for the year ending June 30, 1929, makes the following statement with respect to climate and insect investigations:

"The thermal constant method of determining when codling moth sprays should be applied was carried through the fiscal year, and its accuracy for this purpose was amply demonstrated. By actual comparison of the theoretic dates indicated by it with the actual dates shown by codling moth emergence boxes, it was found that as a rule a difference of not to exceed one day existed between them. The number of temperature stations in 1928 was 38, whereas in 1929 the number was reduced to 7. This reduction was made because smaller numbers gave as good an indication as the larger number and cost much less to maintain."

It will be possible for any one who keeps temperature records such as are described in this paper to learn by observation the number of effective day-degrees which has accumulated on any date on which an important event in the seasonal history of the codling moth may occur, and by recording these he may be able to anticipate their approach every year, however early or late the season may be.

Thus far this discussion has been confined to the use of accumulated day-degrees of effective temperature to forecast the time of the appearance of different events in the seasonal history of the codling moth. Observations made during the past few years indicate that the

same temperature factors may be of use to forecast the time of appearance of a number of other insects.

The following insects may be expected to begin to appear when the number of day-degrees of effective temperature placed after their names have accumulated:

Insect	Day-degrees	Day-degrees
Chionaspis furfura	Young of 1st brood 275;	young of 2nd brood 1500
Chionaspis americana	Young of 1st brood 275;	young of 2nd brood 1500
Chionaspis pinifoliae	Young of 1st brood 275;	young of 2nd brood 1500
Lepidosaphes ulmi (double brooded form)	Young of 1st brood 275;	young of 2nd brood 1500
Lepidosaphes ulmi (single brooded form)	First young 450;	
Aspidiotus perniciosus	Young of 1st brood 725;	young of 2nd brood 2110
Pulvinaria vitis	First eggs 550;	1st young 850
Gossyparia spuria		First young 843
Hemerocampa leucostigma	Larvae of 1st brood 300;	larvae of 2nd brood 1400
Thyridopteryx ephemeraeformis		1st young 575

Further studies will undoubtedly show that the limits of the temperature zones vary for different species of insects and thorough studies of the relationship between insects and temperatures will give us more accurate means of forecasting their appearance and development. Judging from the few observations which have been made on other insects, however, the effective temperatures as worked out for the codling moth may be applied to other insects whose life cycles are comparable to that of the codling moth whose rate of development is not affected to any large degree by humidity or other factors.

Accumulative temperatures based on atmospheric conditions cannot be depended upon to indicate when insects which hibernate under ground will emerge from hibernation, but for many insects that spend their entire lives in the open, the same temperature units of effective day-degrees as have been worked out for the codling moth may be found accurate enough for ordinary forecasting.

In conclusion, the writer wishes to express the hope that greater attention may be given to the relations of climate to insect development, being confident that these relations are sufficiently constant to be of great practical value.

PRESENT STATUS OF THE CLASSIFICATION OF IMMATURE INSECTS[1]

BY

WILLIAM P. HAYES
Associate Professor of Entomology
University of Illinois, Urbana

INTRODUCTION

The present day knowledge of immature insects is incomplete and fragmentary as compared to the information that is available concerning adult insects. The study of immature insects has been neglected, but is of great biological interest because a knowledge of the preparatory stages of insects is essential to an understanding of the many adaptations of insects, whose significance can only be recognized when light is thrown on the immature stages. Comparative studies of immature forms will yield light on the significance of metamorphosis, especially as to the origin and development of this phenomenon which appears in its greatest development in the specialized insects. Certain adaptations of immature insects when fully understood should aid in the application of the biogenetic law to insects and all attempts to correlate insect ontogeny with phylogeny must give careful consideration to the characteristics and peculiarities of postembryonic development. It seems hardly necessary to stress the importance of the study of immature insects. They afford numerous aids in the study of phylogeny and classification when study of the adults fails to furnish the necessary evidence. Moreover, larvae are of great interest because of their habits which furnish abundant material for the study of insect ecology, a much neglected field.

Not only have the structural and functional modifications of immature insects been neglected but the taxonomic aspect is in a deplorable state and there is at present a crying need among the economic investigators for a way out of the present chaos. There is scarcely an economic entomologist but what has dire need for a system of classification of immature insects. To be sure, some work has been accomplished but what little has been done is scattered widely in the ever increasing flood of entomological literature. No attempt has ever been

[1]Contribution No. 150 from the Entomological Laboratories of the University of Illinois.

made to bring together the known facts of larval and nymphal development and not even a bibliography on the whole subject is available.

The present paper is an attempt to bring together some of the materials for the classification of immature insects; the important facts of metamorphosis and some structural characteristics are considered, and some available keys to the immature stages of insects are listed in the hope that others will strive for a further advancement in the classification of immature insects.

Present Status of Classification

Most of the earlier students of entomology devoted their efforts to the study of adult insects, stressing at first the classification, and later, the morphology of mature insects. A few workers such as Swammerdam and Reaumur devoted their attention to the metamorphosis and habits of insects. Led by the great Linneaus, the vast majority of the students of taxonomy, even up to the present day, have confined their attention to the classification of adult insects. Through their efforts new species are being defined and a limited number of descriptions of the egg, larval, and pupal stages are being compiled. These descriptions have been augmented in recent years by the increased interest in economic entomology which is especially evidenced in the United States, as well as some foreign countries, and by the establishment and development of numerous federal and state agencies for the study of insect life. These laboratories have expended a large share of their efforts in making known a vast number of our economically important insects and fortunately the work is still progressing. In spite of the fact that our knowledge of the immature stages of insects is rapidly increasing, it has by no means kept pace with the advance made in the study of adult forms. The available information is scattered widely in the literature and until some effort is made to assemble the present known facts, progress will be slow.

Perhaps the best known groups of immature insects are the Lepidoptera and certain members of several insect orders which are generally referred to under the group term "aquatic insects". The students of Lepidoptera have been among the foremost in advancing the study from the systematic standpoint. This can be explained, in part at least, by the unexcelled beauty of the adults which has led many collectors to rear and study the immature stages, in many cases merely to obtain more adult specimens. It must not be forgotten, however, that many students have been impelled by a desire to know more about the immature insects.

The early stages of aquatic insects are better known because of the ease with which many of the insects can be reared. There are some groups in which only the immature stages are aquatic, others in which both the young and the adult spend most of their life in the water, and only rare instances, as in the case of some aquatic Hymenoptera, in which only the adult is aquatic. The study of fresh-water biology has developed rapidly with the aid of many investigators who are not strictly entomologists, but who have, nevertheless, given some time to the study of aquatic insects. In Europe, Rosseau and others have done an immense amount of work on the classification of water-inhabiting forms. Other entomologists, and they are rare, have been interested and have given some attention to various groups of immature forms. Such workers as Schiödte, Dufour, Perris, Böving, Dyar, Fracker, Yuasa, and Mosher may be considered as initiators of the systematic study of immature groups.

Phases of Insect Development

Insects, as well as other Arthropoda, undergo three distinct periods during their life-history, an embryonic period, a postembryonic period, and an adult period. In the first or embryonic period are comprised the processes of maturation, fertilization, egg cleavage, the formation of the germ layers and the growth of organs and appendages. Naturally, these occur while the insect is still within the egg and the animal is known as the embryo.

Omitting, for the moment, the second or postembryonic period, brief mention is made of the final stage. In the adult stage the insect exhibits all or most of the structures of the body (excepting provisional organs) as evidenced by completely developed appendages and internal organs. In some species the newly transformed adult requires some time for the complete development of the organs of reproduction. In others, for example the ants, a period just after transformation is undergone in which the individuals are not fully colored and, in a still helpless condition, must be nourished and cared for by other members of the colony. Such individuals are termed callows. The insect in this last phase of its life is known as the adult whose chief function is the perpetuation of its kind. This is accomplished by the act of copulation when the female is supplied with spermatozoa for the fertilization of the eggs. The male, however, is not always required for this purpose. As is well known many insects may reproduce parthenogenetically and the males may be entirely lacking, few in number, or appearing only at certain intervals during the seasonal life-cycle of the species.

The second or postembryonic period is that between the hatching of the embryo and the attainment of the adult condition. In some groups of insects the changes during this period are very slight and may be only an increase in size, whereas in other groups very striking and remarkable changes may occur. Also, the groups are not all in the same stage of development when hatched and consequently the greater the difference between the newly hatched insect and the adults, the greater will be the postembryonic changes. When only minor changes occur the development is said to be direct and the type of change is sometimes called direct metamorphosis. If the course of development is devious and each successive change is different, with complicated processes occurring, the development is said to be indirect and is frequently known as indirect metamorphosis. In direct metamorphosis the young and adults are quite similar. This type of development occurs in the Apterygota as represented by the orders Thysanura and Collembola. A somewhat more complicated type of direct metamorphosis is found among these Pterygota in which the wing development is external, as found in Orthoptera, Dermaptera, and some other ten orders. The remaining orders, belonging to the Pterygota such as Coleoptera, Lepidoptera and others, present a complicated change from the larval to the pupal stage and likewise a pronounced change from the pupa to the adult. They are consequently said to have indirect metamorphosis. These two types of development occur in varying degrees among many animals other than insects, but to a less pronounced degree. Entomologists as a rule apply the term metamorphosis to both direct and indirect types of development, whereas some zoölogists consider only the changes occurring in indirect development as metamorphosis.

Provisional Organs

During the postembryonic period, in many insects, certain structures are developed which are for use only during the period of growth and are lost or absorbed before or at the time of the emergence of the adult. Such temporary organs are *provisional organs* and their presence tends to increase the differences between the organization of the immature and adult stages. Some of the provisional structures are the *prolegs* of caterpillars, digging *fore-legs* of the cicada nymph and the *pseudopods* of dipterous larvae. As these organs are essentially structures of the immature stages and not of the adult, the young insects possessing provisional organs may differ from their parents in at least one of the following types of provisional organs:

1. In the form of body segmentation.
2. In the degree of development or number of organs of locomotion.
3. In the degree of color, chitinization or armature such as setae, bristles or spines.
4. In the location or number of glands.
5. In the degree of development of antennae or mouthparts.
6. In the presence or absence of certain external structural characters.
7. In the degree of development of internal structures.

Deegener (1909) has classed provisional organs into "provisional organs of the first order" and "provisional organs of the second order". Those of the first order are those which are characteristic only of the immature stages, such as prolegs, exuvial glands, and osmateria. Organs of the second order are represented by the mandibles of sucking neuropterous larvae, which are also present in the adults.

Escherich has classified immature insects on the basis of provisional organs as follows:

CLASSIFICATION OF LARVAE ON BASIS OF PROVISIONAL ORGANS
(After Escherich from Lochhead, Economic Entomology, p. 343)

Primary Larvae.
Larvae like adult, without provisional larval organs.
Thysanura, Collembola, Mallophaga, Pediculidae, Orthoptera, Isoptera, Corredentia.
Secondary Larvae.
Unlike adults and with a few provisional larval organs.
Ephemeridae, Plecoptera, Cicadidae, Odonata, Coccidae.
Tertiary Larvae.
Unlike adult with numerous provisional larval organs.
Classification of Tertiary Larvae.

A. Larvae without prolegs
B. Larvae with a well formed sternum
C. Larvae more or less chitinized, thorax or at least the prothorax differing from the other segments quite noticeably, large or more strongly chitinized, or otherwise sculptured; head generally with lateral eye points. EXAMPLES: **Rhaphidians, Ant-lions, Carabidae, Dytiscidae, Silphidae, Coccinellidae, Elateridae, Chrysomelidae.**
CC. Larvae weakly chitinized, soft-skinned and mostly whitish, but with chitinized dark head; thorax differing but little from the other segments. EXAMPLES: **White Grubs, Stag Beetles and Dung Beetles.**
BB. Larvae with poorly developed or rudimentary sternum. EXAMPLES **Many Cerambycids, Sirex.**
BBB. Larvae with sternum wholly atrophied or undeveloped.
C. Larvae with a head capsule and typically formed mouthparts. EXAMPLE: **Bark-beetles, Snout Beetles, Bees, Wasps, Ants, Ichneumons, Midges.**
CC. Larvae without a head capsule or well-formed mouth parts. EXAMPLES: **Most diptera.**

AA. Larvae with prolegs.

B. Larvae usually with five pairs of prolegs. EXAMPLES: Butterflies and Moths.

BB. Larvae with more than five pairs of prolegs. EXAMPLE: Sawflies.[1]

MOLTING

The fundamental processes of metamorphosis are *growth, development of wings* and, in rare paedogenetic insects, *reproduction.* Growth can only be accomplished by the shedding of the cuticula, or *molting.* The body, as well as its appendages, is covered by the cuticula in which there is a substance called chitin, the amount of which determines the rigidity or flexibility of the body wall and this is dependent to some extent on the age of the insect. Soon after the deposition of chitin the body wall hardens and becomes inflexible and inelastic so that it becomes difficult for the insect to expand its body during growth. In order to permit expansion, the insect periodically casts off or sheds this hardened layer of cuticula. This process is known as *molting* or *ecdysis,* and the molted or cast skin is the *exuviae.* When the growing insect is ready to shed this hardened, outer, body wall it becomes quiescent for a short period during which the primary or outer cuticula becomes separated from the inner or secondary cuticula. This separation is aided by a fluid secreted from certain *exuvial* glands which is said to act corrosively on the structures beneath the primary cuticula. Finally, the old cuticula splits on the dorso-mesal surface of the head and thorax and after forcing the edges of the rent apart, the insect slowly forces its body out of the old cuticula. The new cuticula is soft and often colorless and some time must elapse to allow for the hardening of the new chitin and for deposition of pigment before coloration is completed. It should be recalled, that not only the body wall and the appendages lose their cuticula, but also the cuticular lining of the alimentary canal, tracheae, and parts of the reproductive organs are molted.

There is a wide range of variation in the number of molts through which insects pass. There is said to be a single partial molt in Campodea and Japyx, and Lubbock has observed the May-fly *Chloen* to molt 23 times. Any number may occur between these extremes and the number may not be constant for the same species. White grubs as a rule molt twice, but some species may molt three times. Certain dipterous larvae (Cyclorrhapha) and some Neuroptera have two molts as a constant number. The number of ecdyses is also variable in caterpillars. May-flies may molt after wings are acquired and Collembola

[1]This group would also include the larvae of Mecoptera.

may molt after reaching sexual maturity. Frequently molts occur soon after hatching. The causal factors of such lack of uniformity may be physiological and are thought by some to be due to food relations.

Most of the stages through which growing insects pass are limited or separated from each other by molts. The intervals occurring between the molts are called *stadia* (single, stadium). The term *instar* applied by Sharp and now widely accepted is used to designate the form assumed by the insect during the various stadia and is used to replace such expressions as "the form assumed at the first molt", or, "the appearance when hatched". The form at the time of hatching is the first instar, that after the first molt is the second instar, and so forth.

Characters Used in the Classification of Immature Insects

As there are marked differences in the body form between the immature stages and the adult, especially in the Holometabola, we find young insects in possession of certain structures which are characteristic only of the developmental period. These have been considered as "provisional organs." It was shown that certain structures like the sucking mandibles of Neuroptera may be carried over into the imago. The presence or absence of some of these organs is now considered. A complete discussion of the countless numbers of larval structures is beyond the scope of this paper and only such generalizations will be made as serve to elucidate the points under discussion.

In the nymphal stages a closer correspondence with the adult stage is to be found than in the larval stage. The three body regions are more marked, the legs are more highly developed, and especially in older nymphs the structures more closely approach the adult form except in the degree of wing development. The body segmentation in nymphs is *heteronymous* or specialized in contrast to the *homonymous* or generalized condition of larvae, in which are recognized varying degrees of specialization. In apodous or footless larvae the metameres of the thorax and abdomen are nearly similar, the animal exhibiting only a head and trunk; frequently, as in some Diptera, the head may be only slightly differentiated. Larvae with well developed legs show more specialization but not to the degree found in nymphs where wing pads are found in addition to the legs, and when the thorax is more specialized. The various degrees of larval specialization are discussed below.

The Body Wall of Nymphs and Larvae

The structure of the body wall in immature insects differs very little from that of the adult except for differences in degree of chitinization, but the appendages of the cuticula, hairs, spines, setae, tubercles, etc. vary in some orders to such an extent that they are useless for purposes of taxonomy whereas in other orders, especially the Lepidoptera, their form and arrangement are sufficiently constant to use in the classification of species. The arrangement of setae is useful in the classification of mosquito larvae and may prove of value in beetle larvae and sawfly larvae. Garman has made use of the various color markings and finer texture of the cuticula to distinguish certain species of cutworms and a deeper study of the shape and structure of the spiracles may prove of importance in other orders, as they have in Diptera where extensive taxonomic use has been made of the minute structure of the peritreme and the shape of the apertures of the spiracles.

The Head of Nymphs and Larvae

The functions of the head of immature insects are practically the same as those of adult insects and consist of the three important physiological processes of *ingestion, sensation,* and *coordination.* The process of ingestion is perhaps of greater importance in young growing insects than in adults, whereas sensation may be less developed, and coordination, brought about by the degree of development of the nervous system, may also be not so well marked. For performing these functions, and chiefly, because the law of cephalization tends to localize a number of structures in the head capsule, the head may be said to contain two rather distinct groups of organs, those which may be classed as essential organs, such as the brain, optic ganglia, cranium, pharynx, and aorta, and those which may be considered as accessory structures, aiding in ingestion, sensation, and coordination. These accessory organs consist of such parts as the muscles, glands, antennae, mouthparts, tentorium, hypopharynx, and the sympathetic nervous system.

In general the head is distinct from the rest of the body and when well developed is known as the *eucephalous type* of head which occurs in both nymphs and larvae. In such heads the integument is generally more heavily chitinized and more resistent to external forces than are the remaining segments of the body. It is ordinarily broadly joined to the thorax but may be separated by a well marked constriction as in the nymphs of the horse louse, *Haematopinus asini* or in earwig nymphs. Sometimes, as in dobson-fly larvae, the occiput may form a

distinct collar at the base of the head. In certain insects, the cephalic region is heavily chitinized while the caudal area, more or less protected by the overlapping of the prothorax, is less heavily chitinized and is capable of being invaginated into the foramen of the prothorax.

In many dipterous larvae the head is indistinct, when it is classified as an *acephalous* or *pseudocephalous* type of head. In such larvae the head is greatly reduced and is retracted within the prothorax, if developed at all. Frequently the anterior margin of the prothorax is so modified that it resembles and is frequently mistaken for the head. An intermediate condition between these two extremes is the *hemicephalous* type of head, which is often found in hymenopterous larvae.

The Antennae

The antennae are two in number as in adult insects. They are inserted near the latero-ventral margin of the head capsule in larvae and near the mesad of the compound eyes in nymphs. The number of segments is usually constant in larvae both for the species and for the instar. They apparently do not increase in number of segments following the various molts as Criddle has found to be the case in nymphs of Locustidae (Acridiidae) and as others have observed in other nymphal forms. In most immature forms the first or proximal segment is the *scape,* the second is the *pedicle,* and those which follow constitute the *flagellum* or *clavola.* When only one or two segments are present the divisions cannot be definitely determined. In white grub larvae, a rounded segment-like protuberance of the body wall on which the antennae articulate has frequently been mistaken for a basal segment. Many coleopterous larvae possess a small supplementary segment on the distal end of the penultimate segment, giving the appearance of a forked or split antenna. Larvae of the Dryopidae and some of the coprophagous Scarabaeidae exhibit such a splitting. However, in the Dryopidae, according to Rosseau, the supplementary segment is on the antepenultimate segment instead of the penultimate, which is narrow and constricted like the distal segment.

Acephalous dipterous larvae have two, sessile, papillae-like structures beneath the mouth which are known as the *"antennal organs".* They occupy the position of the antennae and probably have a sensory function. On the sides of the antennae of certain aquatic Diptera, for example in *Simulium* (black fly larvae) and *Culex* (mosquito larvae,) are appendages bearing cilia or tufts of setae which help to maintain a current of water toward the mouth, thus providing aquatic organisms for food.

Organs of Sight

Compound eyes are usually found in nymphs of those species in which they are present in the adult form. If the adult lacks eyes, which is frequently the case in degenerate forms, the nymph also lacks them. Well developed eyes are present in nymphs of Hemiptera, most Homoptera, Orthoptera and Odonata. In older nymphs *primary ocelli* are also found but there is some doubt as to their ability to function. Frequently, they may be only the simple eyes of the adult showing through the nymphal cuticle.

Compound eyes are never present in larvae which, as a rule, are provided with groups of simple eyes known as *adaptive ocelli.* This type of ocellus is thought to have been brought about by a change in the habits of individuals as we regard larvae as being secondarily developed by adapting themselves to their particular mode of life. Adaptive ocelli usually occur on the sides of the head. In the Perlidae (Plecoptera) and the Ephemerida ocelli are on the dorsal aspect, although these may be adult ocelli showing through the cuticula. Such eyes are distinctly different from the primary ocelli of adults.

Primary ocelli are usually three in number, but maybe only two. It is believed by some workers that the median ocellus represents a fusion of two ocelli, there having been, primitively, two pairs of simple eyes. Because of the marked differences in structure between the two kinds of simple eyes, MacGillivray[2] has proposed the term *ocella* (pl. ocellae) for all simple eyes of larvae to distinguish them from *ocelli* of adults. The number of adaptive ocelli is variable in different insects and may differ in the same species. *Corydalus* larvae may have six or seven on each side. Henneguy (p. 450) cites the following groups which have from one to twenty ocelli on each side of the head.

One ocellus—Lampyridae, Drilliidae, Lycidae, Telephoridae, some Cryptophagidae, Cerambycidae and Curculionidae, phytophagous Hymenoptera (Tenthredinoidea) and Trichoptera.

Two ocelli—Byrrhidae, Melandryidae, Oedemeridae, Tenebrionidae, Nitulidae, Elateridae and some Scarabaeidae (Trox).

Three ocelli—Many Cereambycidae, Tenebrionidae and Coccinellidae.

Four ocelli—Cicindellidae, most Staphylinidae, Pyrochroidae, some Chrysomelidae *(Cassida)* and Coccinellidae.

Five ocelli—Cleridae, Ciodidae, Colydiidae, Mycetophagidae, Heteroceridae, Parnidae, Lagriidae, many Byrrhidae, some Cerambycidae, and many lepidopterous larvae.

Six ocelli—All Carabidae, Dytiscidae, Gyrinidae, Cyphonidae, Erotylidae, most Hydrophilidae, Dermestidae, and many Chrysomelidae, *Sialis* and most Lepidoptera.

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[2]MacGillivray, A. D., The Eyes of Insects. *In* Ent. News, Vol. 31, pp. 97-100, 1920.

Seven ocelli—*Raphidia* and *Bittacus*.
Twenty ocelli or more—*Panorpa* and *Boreus*.

Larvae living in the soil, in wood, or other concealed places have no use for eyes and consequently are blind. Examples of such species can be found in the Scarabaeidae, some Curculionidae, many Cerambycidae, Tenebrionidae and many others. Most hymenopterous larvae, excepting those of the sawflies and their close relatives as well as many Diptera, are without adaptive ocelli. Many aquatic Diptera with well developed heads (*Culex, Corethra,* etc.) are provided with ocelli. In certain Cecidomyidae, scattered pigment spots over the body have been found to be provided with nerve endings which have led certain workers in the past to suggest a visual function similar to that found in many of the lower organisms.

Mouthparts of Immature Insects

Young insects that exhibit gradual metamorphosis ordinarily have the same type of mouthparts as the adult and as a rule they are of the mandibulate (chewing) type; examples are the nymphs of Orthoptera, Isoptera, and others. Those having suctorial mouthparts in the nymphs have the corresponding type in the adults, the Hemiptera, Homoptera and Anoplura.

The common type of immature insect mouthparts in the Holometabola is the mandibulate type which in some groups is carried over to the adult stage. Others in the larval stage possess the chewing type which in the adult is transformed to the sucking or lapping type. The usual biting structures are found in these larvae—a labrum, two mandibles, two maxillae, and a labium which become greatly modified in the adult stage. Henneguy (p. 451) has classified the various types of immature mouthparts as follows:

1. ***Insectes menorhynques.*** **Sucking type in both the immature and adult stages: Homoptera, Hemiptera, and Anoplura.**
2. ***Insectes menognathes.*** **Chewing type in both the immature and adult stages: Orthoptera, Odonata, Neuroptera, Mecoptera, Ephemerida, Trichoptera, Coleoptera and some Hymenoptera.**
3. ***Insectes metagnathes.*** **Chewing type in the larval stage and sucking or lapping in the adult stage: Diptera, Siphonaptera, Lepidoptera, and some Hymenoptera.**

The biting type is the most common but in certain groups it presents striking modifications in which the parts no longer function in a chewing capacity. Some of the parts, especially the mandibles, become organs of piercing and suction. An example of such is found among dytiscid larvae in which the mouth is closed and the mandibles are penetrated by a hollow canal which connects with the esophagus.

The insects are predaceous and their nourishment is the body fluids of their prey, although rarely they can take in solid material. Other examples of this condition are found among the Myrmelionidae, Chrysopidae, and the Hemerobiidae. In these, the mandibles are not penetrated by a canal, but are grooved on the under surface to form a canal with the aid of the corresponding maxillae.

A unique specialization of the mandibulate type of mouthparts is found in the Odonata. The mandibles and maxillae show no special modifications, but the labium is a curious structure, varying in degree of development among the various genera. The labium is normal in the adult stage. It is usually longer than the head in the nymph and possesses a double articulation which allows it to be protruded or retracted. It is thus an extensile and prehensile organ used to grasp food. When retracted it covers the mouthparts, in whole or in part, and it is then called the *mask*, a name applied to it by Reaumur. The submentum of the mask is very long and, when retracted, is usually under the prothorax. The mentum, likewise, is elongated and bears on its distal end a pair of labial palpi which terminate in a *movable hook*. The setae of the mentum *(mental setae)* and other characters of the labium are used to a large extent in taxonomic keys to the nymphs (or naiads) of this order. The movable hooks are used, when the labium is extended, to aid in grasping the prey which is then brought back to the mouth.

In the Lepidoptera there is a marked transformation from the biting type of larval mouthparts to a siphoning structure of the adult. The structures are normal in the larva but during its period of growth a large, invaginated histoblast is developing which produces the elongated maxillae, or more properly speaking, the galea of the maxilla of the adult. This becomes evaginated at the end of the larval period but does not assume its final form until the adult stage is reached. Observers have noted that no adult mandibles are developing within or behind the larval mandibles, so that in the adult the mandibles are either absent or are vestigial.

The mouthparts are fairly well developed among the larvae of eucephalous Diptera, but extreme modification occurs in the acephalous and legless dipterous larvae; in these insects the mouthparts do not appear externally until the pupal stage and do not function until the adult stage is reached. The larval mouthparts are greatly reduced and usually consist of two chitinous hooks which can be extended and retracted, used to lacerate food, and in some insects (Oestridae) serving as organs of attachment or fixation. The hooks, which may be bifurcated, work in a vertical plane and some species use them as

claspers during locomotion. Larval mouthparts of this sort are in no way homologous to the mandibles, maxillae, and labium of other larvae.

The most common examples of insects having sucking mouthparts in both the young and adult stages are found in the orders Homoptera, Hemiptera, and Anoplura. The nymphal mouth organs consist of a labrum, epipharynx (or possibly a combined labrum-epipharynx), two mandibular stylets, two maxillary stylets, and a sheath, or scabbard-like labium, with palpi usually lacking. They are essentially like the corresponding adult structures and further description is not necessary here. The sucking types occurring among holometabolous larvae have been mentioned above as specialized mandibulate types (Dytiscidae, Myrmelionidae, Chrysopidae and Hemerobiidae). These modified, sucking mandibles are usually projected cephalad and not folded under the body as are the mouthparts of the Hemiptera and Homoptera.

Other Appendages of the Head

Except for the antennae and mouthparts, the head is generally devoid of other appendages, but the non-functional tracheal gills found on the heads of some Plecoptera should be called to mind. The hypopharynx in nymphs of *Perla* of the order Plecoptera is elongated and extends beyond the glossae and may thus appear as a non-movable appendage of the head.

The Thorax of Nymphs and Larvae

The thorax is the second division of the body and is not as specialized in either nymphs or larvae as it is in most adult forms. Usually the segments are quite similar to the remaining segments of the body and are designated, as are the adults, by the terms *pro-* *meso-* and *metathorax*. In the aculeate Hymenoptera the basal or first abdominal segment is transferred to the thorax during the change from the larval to the pupal stage. This first abdominal segment is the *median segment or propodeum* and the thorax as thus constituted is the *alitrunk* in both pupae and adults.

Thoracic Appendages

The developing wings or wing pads of nymphs are conspicuous appendages of the thorax. The *tracheal gills* of aquatic forms are non-articulating appendages of both the thorax and abdomen. Other appendages are *osmateria*, eversible glands, on the dorsal aspect of the prothorax in *Papilio* and the ventral eversible glands in Notodontidae, Noctuidae, and other lepidopterous larvae. The clothing hairs or setae

and the chitinous tubercles of many caterpillars are also less conspicuous appendages. There may be *setiferous tubercles,* or, if the tubercles are larger and with many hairs, *verrucae,* as found in the Arctiidae. If the tubercle is spinose as found in the Saturnioidea it is known as a *scolus.* Setae that are not constant are known as *secondary setae.* If they are constant and have a definite position and usually a definite number, they are called *primary setae.* In some groups there are certain setae present in all the instars except the first which are distinguished from those present in the first instar by the appellation *subprimary setae.* In the classification of the lepidopterous larvae each of these setae is given a distinguishing name.

The locomotor, thoracic appendages are usually called the "true legs" in contrast to the abdominal legs when they are present. When thoracic legs are present they are, as with the adult, six in number. In a few cases, for example, the larvae of *Passalus cornutus,* the metathoracic pair is much reduced. In this instance, the reduction is due to a modification in which this leg is used as a scraper to stridulate with the mesothoracic leg for the production of sound.

As a rule the same divisions of the leg occur in the immature insect as are found in the adult insect although the segments are usually shorter and the tarsi have fewer segments which sometimes increase in number with the later molts. The tarsus is provided with a single claw in most Coleoptera, Neuroptera and Lepidoptera. The Carabidae, Dytiscidae and Gyrinidae are exceptions to the Coleoptera in the possession of two tarsal claws and some Neuroptera likewise have two claws. *Meloe, Mylabris* and other triungulin larvae are so-called because they possess three tarsal claws of which the median claw is enlarged for piercing whereas the lateral claws are sharp and curved. Riley and others have shown that the lateral claws are two large setae.

The development of the thoracic legs is frequently correlated with the mode of life of the immature insect. If it must search for its food, as with the carabid larvae, the legs are well developed. If food is close by and abundant the legs are less developed and even entirely atrophied in forms that live in their food material. They may have legs in earlier instars, retaining them until food is found after which they cast them off with the next molt. Such forms are usually considered as having a simple type of hypermetamorphosis, especially if other striking changes such as body form occur. Footless, larval insects are common and the loss of these appendages is usually considered as a secondary adaption. The larvae of all Diptera and Siphonaptera are legless. Some Coleoptera, such as the Rhynchophora, Eucnemidae, Buprestidae and many Cerambycidae are apodous. A few Lepidoptera

and all the Hymenoptera except the sawflies are without thoracic legs. All degrees of development between the fully developed leg and the apodous forms can be traced in various groups.

In nymphs there are generally three pairs of well developed legs with the usual divisions. Female Coccidae have none in later instars. The tarsi are from one to five-segmented and in aquatic forms may be greatly flattened and ciliated for swimming. The anterior pair of legs are usually fitted for locomotion but may be modified for prehension in many Hemiptera (*Nepa, Ranatra* and Nabidae). The legs also serve for fixation. A unique structure is the modified leg of the Cicada nymph, which is flattened for digging during nymphal life but normal in the imago.

The Abdomen of Nymphs and Larvae

The abdomen, the largest of the three body regions, comprises all parts behind the thorax. In larvae there is no distinct separation of the terga, pleura, and sterna whereas in nymphs there are usually only terga and sterna present. The pleura are absent and the terga and sterna may or may not be connected by a longitudinal membrane or conjunctiva. Spiracles are usually present and functional in the first eight segments. They may, in some species be present but not functional. The caudal segments gradually become specialized as development proceeds and as a rule differ in the two sexes.

The Cerci

Appendages of the abdomen may serve in the capacity of sensation, locomotion, respiration, or fixation, and for reproduction in the adult stage. The cerci are considered as being sensory in function, serving in a tactile or olfactory capacity. They have been variously regarded as appendages of the ninth, tenth, and eleventh segments. Comstock considers them to belong to the eleventh segment. Their position may vary in different groups. They are always paired and exhibit a great deal of variation in size and shape. They may or may not be segmented and composed of from one to many segments. Many segmented cerci are found in the Thysanura, some Orthoptera (Mantidae, Blattidae and some Gryllidae), the Ephemerida and the Plecoptera. In the Embiidoptera they are two-segmented. Those composed of one segment, and therefore considered as non-segmented, are found in some Orthoptera (Locustidae, Tettigoniidae, Phasmidae and some Gryllidae), Odonata, and the Dermaptera. In the Dermaptera they are strongly curved to form the "pinchers." The cerci in the odd Mayfly genus *Prosopistoma* are retractile.

In some Thysanura (*Machilis, Lepisma et al*) and in the nymphs of the Ephemerida, besides the lateral pair of cerci there is a median appendage called the *median caudal filament* or the *alacercus.* It is quite similar to the many-jointed cerci but is thought to have a different origin in that it is considered a prolongation of the tergum of the last abdominal segment.

Locomotor Appendages of the Abdomen

The so-called "false-feet" of caterpillars, sawfly larvae, and scorpion-fly larvae are usually known as *prolegs.* Objection has been raised to the use of this name by some authors who maintain that a proleg should be an appendage of the prothorax. Accordingly, such other terms as *uropod, larvapod* and *propleg* have been suggested as substitutes. The prolegs are non-articulating appendages of most of the abdominal segments. They are used in locomotion and for fixation. In shape, the prolegs are usually cylindrical or conical and in the Lepidoptera are terminated by a series of hooks or crochets. Embryologists have shown that the evanescent abdominal appendages of the embryo are retained and transformed into functional prolegs in those species in which prolegs are present and that the embryonic appendages disappear in those species without prolegs.

In the Tenthredinidae and Mecoptera the crochets are absent but in Lepidoptera they are important structures in the classification of caterpillars. The arrangement, size, and shape are quite varied. They are said to be absent in *Agriotis* and the European genus *Hepialus.* They are ordinarily arranged in a complete or incomplete circle, in transverse bands or in the shape of an ellipse and may be of the same length or regularly graded in length (uniordinal), alternately composed of two lengths (biordinal) or of three lengths (triordinal). When there are present one or more rows of small, rudimentary crochets at the bases of the functional hooks, the arrangement is known as *multiserial.* In some cases there is a longitudinal band of crochets on the inner side of the proleg and a weaker band of scattered hooks on the outer side. This sort of an arrangement is called a *pseudocircle.* The apex of the proleg is called the *planta.* To the planta is attached a muscle which when contracted may cause the proleg to be completely retracted.

The location and numbers of pairs of prolegs is quite variable. Most of the Lepidoptera have five pairs on the third, fourth, fifth, and sixth segments and a terminal pair on the posterior segment. Imms calls the first four pairs "abdominal feet" and the last pair "claspers." All serve more or less as claspers. Caterpillars as a rule never have prolegs on the first, second, seventh, and eighth segments and they may

sometimes be absent on other segments thus having fewer than five pairs. The early instars of many Noctuidae have only three pairs or only rudimentary prolegs on the fifth, sixth, and tenth segments, but after the third molt the prolegs of the third and fourth segments appear. In the subfamily Plusinae of the Noctuidae and in some other subfamilies the prolegs of the third and fourth segments are permanently absent. Other noctuids *(Catacola, et. al)* have only four pairs of prolegs. In the family Geometridae prolegs are present only on the sixth and tenth segments. Other geometers may have prolegs on the fifth segment as well. Caterpillars with fewer than five pairs of prolegs usually have the "looping" habit of locomotion. The anterior part of the body is fixed with the thoracic legs and the prolegs are drawn forward causing the body to become strongly arched, or looped, after which the thoracic legs are released and pushed forward to become attached again during which time the prolegs remain firmly attached. The caterpillars of the genus *Micropteryx* are exceptional in having eight pairs of prolegs while certain leaf-mining Lepidoptera are totally footless and are called "slug caterpillars." Examples of this condition occur in the genera *Eriocraina, Phyllocnistis* and *Limacodes.* In some genera the anal prolegs are extremely elongated and are retractile. They are said to be used as organs of defense against parasitic insects attempting to oviposit on the caterpillars.

The larvae of sawflies (Tenthredinidae) are sometimes called "false-caterpillars." They are usually distinguished from true caterpillars by having more than five pairs of prolegs. The number varies in the various subfamilies. The Xyelinae have prolegs on each abdominal segment. In other groups they are present on segments one to nine but in the Pamphilinae and Oryssinae the prolegs are absent. Scorpion-fly larvae (Mecoptera) have, besides the three pairs of thoracic legs, a pair of prolegs on each of the first eight abdominal segments and none on the last two segments. Others may have no prolegs at all.

Structures serving as abdominal feet are found in a number of other groups of insects. Certain coleopterous larvae have a pair of well-developed prolegs on the anal segment. In certain Elateridae they are more or less retractile. In the beetle family Oedemeridae certain genera *(Asclera* and *Nacerdes)* have on some of the anterior abdominal segments paired outgrowths provided with strong setae which aid in locomotion. Some dipterous larvae belonging to normally footless groups may possess structures on both the thorax and abdomen which serve in locomotion. They are merely cuticular outgrowths in pairs on various segments depending on the individuals and usually termin-

ated with chitinous hooks. These outgrowths are known as *pseudopods.* Some species bear pseudopods on the abdomen whereas others have them on both the thorax and abdomen. In *Dixa* two pairs are located on the first and second abdominal segments. In Dicranota five pairs are formed on the last five segments. In the rat-tailed maggot, *Eristalis,* seven pairs are located on the first and third thoracic and the first five abdominal segments.

Miscellaneous Appendages of the Abdomen

In many larvae appendages occur variously disposed over the abdomen, whose functions are not fully understood. In the larvae of *Lampyris* and certain Carabidae there is a terminal, cylindrical tube which may possibly be used in locomotion. Tiger-beetle larvae (Cicindelidae) have on the back of the abdomen two tubercles with strong hooks which are said to aid in fixing the larva firmly in its burrow when struggling with its prey. Many cerambycid larvae have protuberances on both the dorsal and ventral surfaces which aid in progression. Among the Sphingidae and certain Bombycidae a strong chitinous spine found on the dorsum of the last abdominal segment probably serves as an organ of defense.

Ventral suckers found in the Blepheroceridae are located in a median row on the ventral abdominal segment. They are unpaired, usually six in number, and are thought to have been developed from the embryonic abdominal appendages, representing a fusion of these structures. On the sides of these suckers are digitate processes which have been considered by Kellogg (1907) to function as gills. The suckers themselves serve to fix the larvae to stones in swiftly running water. In the Simulidae a foot-like sucker on the ventral side of the thorax is formed by the fusion of a pair of pseudopods and is provided with hooklets for fixation. The larvae of Trichoptera have two terminal hooks which serve to hold them in their cases and while walking. Gyrinidae have four chitinous terminal hooks.

External Respiratory Structures of Nymphs and Larvae

Adult insects as a rule respire only by means of spiracles. Among immature insects also, normal spiracular respiration is common but many remarkable modifications are found among nymphs and larvae. In general there are four means by which insects breathe, (1) normal *spiracles,* (2) *tracheal gills* which are either external or internal (anal), (3) *blood gills,* and (4) *cuticular respiration,* usually called cutaneous respiration, in which oxygen passes through thinly constructed parts of the body wall. The greatest modifications of the

normal condition are found in aquatic forms which present some interesting observations in regard to the methods of respiration.

Modifications of the common spiracles occur principally in variations in the number and location of functional spiracles. When one or more pairs of spiracles are functional the method of respiration is the open or *holopneustic* method of respiration and when closed is the *apneustic*. If all spiracles are functional the system is *peripneustic;* if only the last pair, it is *metapneustic;* and if both the first and last pair is used the system is *amphipneustic*. These types occur most frequently among the Diptera.

From the standpoint of apneustic respiration the immature stages of aquatic insects present many interesting types. Chief among these are *tracheal gills* which are outgrowths of the body wall forming special appendages of the body for obtaining oxygen from the water. Tracheal gills may be external or internal but are more often external. They are penetrated by branches of the main tracheae from which finer tracheoles ramify to all parts of the gills. The form and location of tracheal gills vary considerably. External tracheal gills may be either *filamentous* or *lamelliform* (plate-like). Filamentous gills occur either isolated or in groups. They may be found on the head in some Plecoptera, on each side of the abdomen, on the dorsal and ventral parts of each segment, or they may occur in groups as in the Trichoptera. They occur singly on the sides in *Sialis* or singly on the ventor as in *Sisyra*. Gills may appear to be segmented appendages. In *Cnemidotus* they are dorsal and articulated. Certain gills may be covered with setae and are said to be plumose. These are usually more rigid in structure. Such types are found in the beetle larvae *Gyrinus* and *Hydrophilus*. Other groups may have tracheal gills on both the thorax and abdomen as in *Rhyacophilidae* (Trichoptera), on each side of the anus (*Perla*), at the base of the maxillae (*Chirotonetes*), or at the base of the legs *(Nephelopteryx)*. Plate or lamelliform gills may be plate-like or leaf-like *(foliaceous)*. Like other gills the form and location is variable. The most common lamelliform gills are those found on the end of the abdomen of damsel-fly nymphs, or those on the sides of the abdomen in May-fly nymphs. If gills are external and visible they are termed *nudibranchs*. If they are hidden or partly concealed, they are designated as *cryptobranchs*. An example of hidden or partly concealed gills occur in the Ephemerid genus *Prosopistoma* in which outgrowths of the body wall form a sort of carapace which conceals the abdominal gills.

Internal tracheal gills occur most commonly in the dragon flies (Anisoptera) and the Agrionidae (Zygoptera) where they are found

in the rectum. In *Aeschna* they consist of six papillae, in *Libellula* they are formed into transverse plates which are penetrated by tracheae. These gills function when water enters the rectum through a special valvular apparatus and bathes the gills, thus permitting an interchange of respiratory gases. According to Rosseau the larvae of certain Diptera, for example, *Culex, Eristalis* and certain *Psychodidae* have rectal gills as well as some May-fly nymphs, *Baetis and Clöeon.*

Blood gills are usually tubular appendages, very delicate and capable of being evaginated and filled with blood. As a rule they do not contain trachea or at most some unimportant branches. Blood gills occur commonly in the Chironomidae. An intermediate type between the tracheal and blood gills occurs in the Ephemerida in which blood and tracheae are found in the caudal appendages.

Identification of Insect Eggs

The knowledge of the specific identity of a particular insect egg is frequently important, especially, if the species in question is a pest of economic importance. Such a knowledge enables one to predict the possibility of insect outbreaks. Many of our economic species are recognized in the egg stage by the economic entomologist. Other groups are known by specialists. Few attempts have been made to produce keys for the identification of insect eggs. Perhaps the most notable attempt of this sort is that of Scudder (1889) when he presented keys for the identification of butterfly eggs. A few other groups, especially aquatic, have been considered in key form, among which may be cited the key to eggs of Hydrophilidae by Richmond (1920). Mosquito eggs have been keyed by Mitchell (1907) and others, and those of sand flies (Phlebotomus) by Howlett (1916). Heidmann (1911) has considered, in some detail but without keys, the eggs of Hemiptera.

Some Important Keys for the Identification of Larvae

No keys are available and little is known concerning the immature stages of the primitive insect orders Thysanura and Collembola. In those orders having a direct or gradual metamorphosis, of which the young are known as nymphs or naiads, a number of keys are available, especially for aquatic insects. Keys to Holometabolous forms are more numerous but many are still untouched. It is the hope of the writer to publish soon a complete bibliography of these works. Here mention is made only of the most comprehensive keys in each of the principal orders. For a complete citation of the papers listed, the reader is referred to the Zoölogical record of corresponding date.

In the Orthoptera no American keys are available, but the work of Criddle (1926) includes good figures and useful descriptions of grasshopper nymphs. May-flies are difficult to identify when immature. Important keys to special American groups are those of Needham (1905), Clemens (1913 and 1915), Murphy (1922), Walley (1930), Needham and Needham (1927), Ide (1930), and McDonnough (1931).

Many keys to Odonata have been published; the more comprehensive and recent are those of Garman (1917 and 1927), Needham and Needham (1927), Howe (1918, 1922, and 1925), Needham and Haywood (1929). Walker has published separate keys to many genera.

The Plecoptera have not been well worked. Frison (1929) has worked up keys to winter stone-flies and there is to be published soon a comprehensive work by Claassen which will appear as a Thomas Say Memoir of the Entomological Society of America. Needham and Needham (1927) have produced keys to genera.

No American keys to Thysanoptera are available but Priesner (1926) has a key to those of Malayian forms. Hemiptera are worked in many aquatic groups. The only terrestrial species worked up are the Pentatomoidea (Hart, 1919).

Neuroptera are better known in the aquatic species. Smith (1922) has given us a key to Chrysopidae. Comprehensive keys to families of Coleoptera are those of MacGillivray (1903) and Rymer-Roberts (1930). An important work on this order by Böving and Craighead is now in press. Space can not be taken to list the many keys to individual families.

In the Trichoptera important works are those of Betten (1901), Krafka (1915), Lloyd (1921), Sibley (1926), and Iwata (1928), the last citation being a key to Japanese species.

In the Lepidoptera, the most important and comprehensive keys to the order of American species are those of Fracker (1915) and Forbes (1923). Many keys are available for families and genera.

In the order Diptera are to be found many keys to lesser categories. The only comprehensive work is that of Malloch (1917), which treats of the order exclusive of Pupipara. A number of works on aquatic species are known and a few terrestrial families have been keyed.

Immature stages of the Hymenoptera are notably untouched; except for the works of Yuasa (1922), Bird (1927), and Middleton (1922) and a few earlier workers on the Tenthredinoidea, the order is practically untouched.

Keys for the Identification of Pupae

Although there is less need for diagnostic keys to pupae than to larvae, at times they are helpful. Only a few groups have been so worked. Except for Mosher's (1916) key to the pupae of Lepidoptera, no other work deals with the entire order. Other papers by Mosher on lepidopterous pupae were published in 1914, 1917, and 1918. Other keys to Lepidoptera are Heinrich (1919) on European Corn Borer allies, Hutchings (1924) on Cossidae, Packard (1905) on Ceratocampidae, Hart (1896) on Pyralidae, and Forbes (1910 and 1923).

The keys to coleopterous pupae are practically negligible. Satterthwaite has recently published (1931) a key to the genus Calendra. More are available for Diptera, especially the works of Green (1921 and 1925) on Pupipara and the numerous small keys to Culicidae. As far as the writer is aware, no keys to pupal Hymenoptera are known.

ERRATA

Page 203. Footnote should be changed to read: Contributions from the Zoölogical Laboratory, University of Illinois, No. 414.

Page 222. Footnote should be changed to read: Contributions from the Zoölogical Laboratory, University of Illinois, No. 415.

Page 228. Footnote should be changed to read: Contributions from the Zoölogical Laboratory, University of Illinois, No. 416.

DISTINCTIVE SKULL CHARACTERS IN SPECIES OF THE GENUS AMBYSTOMA*

BY

WILLIAM F. HOHEISEL

University of Illinois, Urbana

INTRODUCTION

The skulls of amphibia in the order Caudata show interesting modifications and differ much from one another, but all agree in the following respects: (1) absence of the quadratojugals; (2) a parallel relation of the palatines or vomeropalatines with the axis of the cranium; and (3) the large size of the parasphenoid.

The separation of the frontal and parietal bones and the occurence of paired orbito-sphenoids are characteristic.

Lower types such as Necturus, Siren, Proteus, and Amphiuma, have a long, narrow type of skull which throughout life remains in much the same condition as that of a tadpole or larval salamander. Internal to the membrane bones the roof and floor of the cranial vault are formed of fibrous tissue and not of well developed cartilage. The epi-otic regions of the skull are ossified, forming large bones external to and distinct from the exoccipitals. The Stegocephalia are the only other amphibia which have these elements separately ossified. Nasals are sometimes present, sometimes absent. Teeth are usually borne on the vomers, premaxillae, pterygoids, dentaries, and angulosplenials. The suspensorium is directed forward.

Higher types of amphibia, such as the salamanders, have broad, wide skulls. In these the suspensorium is found projecting nearly at right angles to the cranium, instead of being forwardly directed. The maxillae are usually well developed, and the premaxillae are completely ankylosed together. There are no palatines. In the otic region the prootics are found distinct from the exoccipitals, and the latter are ossified continuously with the epi-otics and opisthotics.

Of the family Ambystomidae, Cope (1887) says: "The Ambystomidae are of particular interest in the Urodela as furnishing connecting links between the ordinary types of the order and those larger species which we suppose to be characteristic of former periods of the earth's history. It also furnishes us with transitional conditions

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*Contributions from the Zoölogical Laboratory, University of Illinois, No. 410.

of characters which have been regarded as indicating very diverse origin and nature." The species are mostly of large size, and probably confined to North America with the exception of a species in India.

A rather large series of characters restricts the family. The ethmoid bone is lacking. There is a fusion of vomer and palatine to form the vomero-palatine. The palatine portion is a pointed process which projects laterally from the parasphenoid. The orbito-sphenoid is separated from the prootic by a tough, membraneous wall. The internal wall of the vestibule is ossified. There are conspicuous prefrontals and pterygoids present, and the premaxillae are fully developed. Dentigerous plates are lacking on the parasphenoids.

This paper involves a comparative study of the skulls of six species in the genus Ambystoma. Distinctive characters are analyzed in terms of the factors affecting developmental mechanics. The significance of the genus and the importance of a comparative skull study are also discussed.

The entire genus numbers eleven species. The names of these, and their distribution, are listed below, after Stejneger and Barbour (1923).

Name	Range
A. annulatum Cope	Arkansas.
A. cingulatum Cope	South Carolina to north; Florida and Alabama.
A. decorticatum Cope	Coastal region of south; Alaska and British Columbia.
A. jeffersonianum Green	Canada (to Hudson Bay) and New England, south to Virginia, Illinois, and Arkansas.
A. macrodactylum Baird	Northern California, to British Columbia, Idaho, and Montana; probably to and in Iowa.
A. maculatum Shaw	Nova Scotia west to Wisconsin, southward to Georgia and Texas.
A. microstomum Cope	South Carolina to Texas; north to Ohio, Illinois, and possibly Canada.
A. opacum Gravenhorst	Massachusetts to Florida; west to Lousiana and Texas, Mississippi basin north to Arkansas, Missouri, Indiana, and Illinois.
A. paroticum Baird	Northern California, to British Columbia, Vancouver Island.
A. talpoideum Holbrook	South Atlantic and Gulf States, Louisiana to Illinois.
A. tigrinum Green	Widely distributed over almost all United States, each of the Cascade Range and Sierra Nevada, and extending ing southward over the northern portion of the Mexican plateau.

Ambystoma texanum, formerly listed as a separate species, is now considered as identical with *A. microstomum.* The names *Siredon, Axolotl, S. pisciformis* and *S. mexicanus* are still used for denoting the persistant larval condition of *A. tigrinum.*

Osteology of Ambystoma opacum

The description which follows will answer in general for any of the species as far as identification of the bony elements is concerned. It is chosen because it represents a sort of intermediate type, having neither an excessively broad brain case, nor one especially elongate.

The Dorsal View of the Skull

The skull (fig. 1) presents a series of smooth, graceful arcs and curves which immediately suggest a symmetry of the whole. Considering the various paired elements, this symmetry is more apparent than real. The antero-lateral part of the skull describes a partial ellipse, the anterior part of which is formed by the premaxillae (pm) meeting together in the midline and articulating with the maxillae (m) laterally and posteriorly. These bones extend the arc to about half the linear dimension of the skull, which is slightly longer than it is wide. Along the mid-dorsal plane the premaxillae also send up large, blade-like frontal processes (fpm) which are closely approximated anteriorly, but diverge slightly in the posterior direction. Laterally they overlap the nasals (n), and posteriorly the frontals (f). It is a general rule that the anterior bone overlaps the element posterior to it. The maxillae, near their junction with the premaxillae, send up an ascending ramus (ar) which articulates with the prefrontals (pf) laterally. The nasolacrimal duct bears a relation to it medially and posteriorly (nld). The external nares (nc), oval in shape, are immediately back of the premaxillae and originally are covered by membrane and a nasal roof cartilage. A small bony element, the septomaxillary (sm) is found in the nasal capsule near the ramus of the maxilla. It is irregular in shape and bent upon itself medially, where it faces the naso-lacrimal duct. A foramen is usually evident in the bone. Primarily it serves for the origin of the muscle dilator naris accessorius. In the Urodela it is found to be an ossification of the cartilage in the posterior wall of the nasal cavity. The work of Lepage (1928) indicates "a chondral origin for the septum." Gaupp considered the homology of the bone in anurans, urodeles, and sauropsida as settled.

The nasals (n) are thin plates of bone, irregular in contour but approximating a wedge. Each bone presents a straight margin toward the nasal process of the premaxilla; a slightly concave margin toward the external nares; and a somewhat convex lateral border which articulates with the prefrontal and is extended posteriorly to articulate with the frontal.

It has already been indicated that the maxilla forms the lateral boundary of a partial ellipse, with the result that the posterior limit becomes far removed from any direct bony attachment with the skull. Its ramus describes an arc directed medialward and slightly posterior and this is continued by the prefrontal in such a way that these bones diverge from one another, leaving an interspace in which part of the vomero-palatine is displayed beneath (v, pa).

The prefrontals are large, irregular, six-sided bones. They are partially overlapped by the ascending ramus of the maxilla. The free lateral margin contributes to the orbit in front, and medially as well, where it helps to form the brain case. Its posterior limit usually indicates the narrowest portion of the brain case. Medially the bone presents two sides, the anterior overlapped by the nasal, whereas the posterior overlaps the frontal. Anteriorly, a small, slightly concave margin borders the external nares. This wedge of bone was evidently overlooked by Parker (1876) who speaks of an "articulation of the ramus of the maxilla with the nasal" at this exact point. The bone is extended under the ramus of the maxilla for some little distance.

The frontal (f) is an irregular, long, flat bone with five distinguishable sides and pointed anterior and posterior extremities. Anteriorly, the bone is overlapped for some distance by the nasal and frontal processes of the premaxilla and extends under these almost to the external nares. Medially, the articulation of the two frontals is serrated. Posteriorly the articular faces are found ventral on the bone because of the overlapping of the frontals on the parietals. Laterally, the bone is partially covered by the prefrontal. The frontal bones dip slightly toward the median suture, and are closely approximated except near the posterior end, where they become narrow and irregular. One side extends to the mid-dorsal line, while the other runs forward and laterally to the posterior tip of the prefrontal, where it contributes slightly to the medial side of the skull.

The parietal (p), although not as long as the frontal, is more broad and irregular, and were it not for a pointed process arising anteriorly and laterally, the shape would be roughly rectangular. The two bones form a gentle parietal crest along the median line. Posteriorly and laterally the bone displays more character because of its relation to the otic and occipital regions. Four borders can be distinctly recognized. Medially and anteriorly respectively, the facets for the opposite parietal and frontal bones are found. Posteriorly, the bone is modeled well over the endocranium, and correlated growth is suggested here, as well as the presence of the anterior and posterior

semicircular canals. Here the bone presents an angle as it descends posteriorly (ap), to end in a lobulated margin which overlaps the fore part of the occipital roof.

The occipito-auditory region is well ossified (a). There is a well defined prootic (pr) which is distinct from the exoccipital and is visible dorsally as a protuberance near the parietal angle. Medial and posterior, the articulation is with the parietal which partially overlaps it in this area. Laterally and posteriorly it articulates with the squamosal. The opisthotics and epiotics are co-ossified with the exoccipitals, and all sutural landmarks are obliterated. A rather broad tract of cartilage still separates the two sides of the occipital segment. The otic capsules display considerable character and suggest the canals of the labyrinth. The capsules are in part overlapped by the parietals and squamosals. The condyles are massive, with a convex posterior surface and sharp, lateral angle. The foramen magnum appears crescent-shaped in dorsal view (fm).

The squamosal (s) is found posteriorly and laterally on the skull where it overlaps the otic capsule and articulates with the prootic. The bone is a dense, strong plate, knobbed and transversely ridged above and below; spiked in front and lobate behind. Dorsally it is smooth and superiorly a pronounced groove suggests muscle attachment, as does a small, sharply pointed process immediately posterior to it. The quadrate (q) articulates with the distal ventral surface. This bone, and the pterygoid are partially visible in dorsal view.

Generally, the bones on the dorsum of the skull of Ambystoma opacum are characterized by their smoothness. The contours are gentle and sweeping, and one gets the impression of a clean-cut skull.

Lateral Relations of the Cranial Vault

The lateral walls of the cranium immediately in front of the otic region are unossified for a distance between the exit of cranial nerves II and V (figs. 2, 3, 4). This portion is covered by membrane. Anterior to this, however, are found the ossified, paired orbito-sphenoids, covering a distance from the exit of the second nerve (which forms a partial foramen in the bone) to a short distance behind the internal nares or nostrils (in). Laterally, the bone is slightly convex, whereas the medial surface is concave. It articulates above with the parietal and prefrontal; below with the parasphenoid and the vomero-palatine.

The prootic (pr) articulates above and below with the pterygoid.

Ventral View of the Skull

In ventral view (fig. 2) the premaxillae and maxillae display a concave surface which ends in a thickened margin for the close-set teeth (t). The teeth are conical and show a bulb-shaped enlargement on the distal ends. Dorsally, the palatal portions of the bones are not well developed, and overlap the large vomero-palatines. This is true except in the median plane, where the removal of the internasal cartilage (fs) from between the vomero-palatines of the two sides exposes the frontal processes of the premaxillae.

The large vomero-palatines (v) extend backward on the cranium for about a third of its length and present a concave border medially. The teeth-bearing palatine portions (pa) extend laterally as pointed processes. Anterior to them, the lateral borders are notched to inclose the internal nostrils (in). The deficient side of the foramen is in each case filled in by a ligament. From here the lateral borders are continued forward and outward to the maxillae. Medially and posteriorly for about one fourth of the length of the bones, an interspace discloses the most anterior extension of the parasphenoid (e). The tooth-bearing portion discloses the suture of the bones of the two sides. All teeth point posteriorly and are ankylosed. The vomero-palatines, in the region of the mesial border of the suspended (free) portions of the bone, send out a wedge-shaped slip which articulates with the lateral border of the parasphenoid and above with the tubercle-like anterior extremity of the orbito-sphenoid (seen to better advantage in Fig. 8, pvp).

The parasphenoid is a large, unpaired, thick bone, forming practically the entire ventral floor of the cranium and extending from the level of the internal nares anteriorly to the foramen magnum (fm) posteriorly. Its six sides are fairly symmetrical. In the mid-line it displays a prominent ridge, on each side of which the bone is appreciably depressed. Anteriorly, the sides converge under the vomero-palatines to a blunt point. About one fifth of the parasphenoid is overlapped by the vomero-palatines. The anterior half articulates with the orbito-sphenoid dorsally. Posteriorly, the unossified basi-occipital and basi-sphenoid regions are covered and the lateral extensions of the bone come into relation with the bulging, bony floor of the otic capsule. Here a slit-like indentation of the bone is obvious. It transmits a large branch of the seventh nerve (VII). Dorsally, it articulates with the prootic.

As indicated, the primordial basi-cranial axis is covered by the parasphenoid. Laterally and posteriorly, however, the condyles of the

exoccipitals and the floor of the optic capsule (vestibule) are prominent. The foramen for cranial nerve IX is lateral and anterior to the condyles. Because of the bulbous nature of the floor of the ear capsule, the term "bulla" is not inappropriate. The small stapes consists of a disc-like piece of bone, the operculum, with a short columella. More directly posterior and lateral, the bulla is stoppered with a partially ossified disc of cartilage. The ear capsule itself is directed backward, downward, and lateralward. It occupies practically the entire postero-lateral part of the vault from the occipital condyles to the ventral pterygoid articulation.

The pterygoid is roughly triangular in outline. From ventral view its surface is dominantly convex. The contours suggest smooth-flowing lines. The apex of the bone is directed outward and forward; its base, backward and inward. The posterior portion is spatulate. The anterior, inferior portion is rounded and thick and the anterior border considered entire, is rounded. The articulations are as follows: anteriorly and medially with facets on the prootic; posteriorly and inferiorly, with the quadrate.

The quadrate, which is dorsal to the pterygoid and intermediate between it and the squamosal, is for the most part ossified. The knobbed condyles are readily distinguishable. Posteriorly, the element shows a bulb-shaped enlargement which functions as an attachment of the hyoid, while ventrally and laterally is a saddle shaped articulation for the articulare of the lower jaw. The remainder of the bone might be described as a splint, in relation ventrally and laterally with the squamosal.

Lower Jaw

The mandible or lower jaw has three closely articulated elements which are duplicated on each side. The dentaries meet in an anterior symphysis and form about two thirds of the arc of the jaws, and the angulare which is medially articulated to the dentary by a long, forward projecting process, incloses the partially calcified articulare. The dentary bears the teeth, which are closely set and knobbed. Parker mentions a tooth-bearing splenial, but I have been unable to identify such a bone in this species.

The Articulation of the Lower Jaw with the Quadrate

Two ligaments are associated with this joint, (1) a ligamentous round band connecting the posterior tip of the maxilla with the anterior tip of the pterygoid, and (2) a ligament which binds down the proximal

end of the ossified portion of the hyoid with the articular cartilage of the quadrate. This added articular cartilage is found posterior-superior to the quadrate condyle and extends somewhat laterally. Anteriorly, it borders the squamosal. It would seem that because of the attachment of the hyoid in this position, some support would be given the articulation of the lower jaw with the quadrate posterior and medially.

The articular portion of the lower jaw is roughly cone-shaped (a broad cone with the apex above). The superior and anterior portions of this ascending ramus of the lower jaw is in relation medially with the pterygoid, and anteriorly with a ligament which binds the anterior tip of the pterygoid and the posterior tip of the maxilla at this point.

The posterior and inferior part of the ramus is convex and is received into an intercondylar groove on the inferior surface of the quadrate condyle.

The cartilage bones and dermal bones of the skull may be summarized as follows:

Chondral bones	*Dermal bones*	
prootic	parietal	vomero-palatine
fused epi-otic, opisthotic and ex-occipitals	frontal	pterygoid
orbito-sphenoid	nasal	premaxilla
quadrate—partly ossified	pre-frontal	maxilla
articulare—partly ossified	squamosal	dentary
stapes	parasphenoid	angulare
septo-maxillary, status still questioned.		

Cranial Nerve Foramina

The following consideration of cranial nerve exits is a summary of the findings of Gaupp, Coghill, Drüner, Herrick, and others. Some of these are specific as applied to the Ambystomidae; others are general for the urodeles. One would naturally expect to find slight differences in the relative position of these foramina in the various species in the genus Ambystoma and in individuals of the same species. Many such instances are already recorded. The following is offered as a general treatment of the nerve exits in a type Ambystoma skull.

I. The olfactory nerve perforates the cartilaginous trabeculae on each side. In some urodeles (according to Gaupp) the nerve is incased in the frontal bone.

II. The optic nerve . . . . has its foramen in the lateral wall of the cranial vault in relation with the posterior border of the orbito-

sphenoid. In fact, in most species studied, a partial foramen is found here in the bone itself (see ventral view of the skulls).

III. The oculo-motor nerve leaves the lateral wall of the skull via the membrane connecting the orbito-sphenoid to the prootic. It lies posterior to the optic foramen and usually at the same level.

IV. The trochlear nerve exit is found high up in the lateral wall in relation to the optic and oculomotor foramina which are ventral to it. There are evidently two possibilities—one may be an exit on the dorsal-posterior part of the parietal bone itself, as in *Ambystoma tigrinum*, or it may take its exit through the suture between the parietal and orbitosphenoid, as Gaupp's work indicates. The foramen is quite small, but discernible to the naked eye.

V. The trigeminal nerve leaves the cranium through the foramen prooticum at the boundry of the lateral wall and the otic region, mesial and anterior to the prootic.

VI. In salamanders the exit of the abducens nerve is typically in the forepart of the basal plate, medial to the foramen of the facial nerve, but in the larval *A. tigrinum*, it leaves with the trigeminal through the foramen prooticum.

VII. The relations of the exit of the facial nerve in the larvae of *A. tigrinum* may be considered as fairly typical. In this species it leaves the skull by a separate foramen which is found on the boundry of the basal plate near the ear capsule, and just posterior to the suspensorium.

VIII. The acoustic nerve passes through the medial otic wall.

IX.; X. The glossopharyngeous and vagus nerves both leave the cranium by way of the jugular foramen, which is found anterior and lateral to the occipital condyles.

Comparative Osteology of the Skulls

The skulls vary in size, that of *A. tigrinum* being the largest and that of *A. macrodactylum* being the smallest. Actual dimensions of the skulls used are appended in a separate table.

A comparison disclosed some interesting and rather extensive differences. The most obvious ones so modify important regions of the skull as to make them diagnostic.

Some of these involve the shape of the brain case. Examination of the figures discloses three general types. *Ambystoma talpoideum* (figs. 7, 8) has the broadest brain case, whereas *A. microstomum* (figs. 9, 10) has relatively the most elongate type. In the latter, the sides are

straight and practically parallel, whereas in *A. talpoideum* the dorso-lateral margins are irregular. *Ambystoma opacum* (figs. 1, 2) represents an intermediate type of skull, its concave lateral margins effecting a gradual expansion of the cranium in front and behind. The skull of *A. maculatum* is similar in this regard, whereas *A. macrodactylum* closely approximates the elongate type of *A. microstomum*. The skulls of *A. tigrinum* and *A. talpoideum* represent departures which are even distinctive for the brain case, the lateral contour in the former and the extreme width in the latter being sufficient to isolate them from other species.

The anterior arc formed by the premaxillae and maxillae seems to change in the separate species, being circular in *A. tigrinum* and elliptical in *A. opacum*. The arcs in *A. talpoideum* and *A. microstomum* are more angular, and in the last, a more pointed fore-part of the skull is evident. Since this arc reflects its counterpart, the mandible below, and possibly other mechanical factors suggested by the suspensorium, measurement of any phase of this arc might prove useful. Lines could be drawn from the symphysis of the premaxillae to the posterior tip of the maxillae and along the mid-dorsal line, respectively. The angle between the two would be a measure of the trend of the maxillae posteriorly. Another noticeable feature of this anterior arc is that it extends posteriorly for varying distances in the separate species. This extension differs from less than one-half to almost two-thirds the linear dimension of the skull.

A reference to the ventral views of the skulls shows that the vomero-palatines are deficient in bone near the mid-line, and display medial borders which are variable for the species. These outline a fossa (fs) (when the internasal cartilage has been removed) which is distinctive in each case.

The internal nares, found as partial foramina in the vomero-palatines, vary in completeness and shape.

Perhaps the last of the very obvious features of the skulls is the relative extent of the bones comprising the roof of the cranial vault. The frontal processes of the premaxillae, the prefrontals, and the frontals figure most strongly here. Certainly their relation to landmarks such as the prootics, anterior tips of the pterygoids, posterior limits of the maxillae, etc., change in the different species. The extent of variation of this character in individuals of the *same species* has not been determined. For another comparison, their extent could be referred directly to the linear dimension of the skull in each case.

SUMMARY

The *Ambystoma talpoideum* skull is distinctive not only because of its broad brain case but also because this broadness is reflected in the wide character of the separate bone pairs which all contribute to the general effect of massiveness. Bony markings are accentuated.

Although *A. opacum* and *A. maculatum* resemble each other in brain case outline (of the intermediate type) and by a general smoothness in borders and surfaces, a more minute study yields several differences. The *A. opacum* skull is more flattened anteriorly from above downward, whereas in this species, the prefrontal is six-sided, it is practically crescent-shaped in *A. maculatum*. The transverse diameter of the cranial vault is appreciably greater in the latter species (relatively speaking) and the pterygoid bone presents a more straight mesial border, in contrast to the convexity found in *A. opacum*. Especially because of the differences noted above, a space bounded anteriorly and laterally by the maxilla, medially by the prefrontal and parietal, and posteriorly by the parietal and pterygoid, is changed in contour and presents a key to the analysis of differences which are at first imperceptible in a comparison of very similar skulls such as the above. This space changes radically when species such as *A. opacum* and *A. tigrinum* are compared.

Mention has been made of the fact that *A. microstomum* and *A. macrodactylum* possess the elongate type of brain case, showing a proportionately smaller transverse diameter. Segregation depends on a series of minor characters, the constancy of which can be determined only after a more adequate number of skulls has been studied. The disposition of the parietal bone over the occipito-auditory region is different in the two species. In *A. microstomum*, the bone more closely approximates the squamosal and the prootic, whereas in *A. macrodactylum* no portion of the bone is contiguous with the squamosal, and the prootics are much more visible dorsally. A definite parietal angle is evident only in *A. microstomum*. In general, there seems to be greater conformity of the parietal and parasphenoid bones with the occipito-auditory mass in *A. microstomum*. There seems to be a more forward inclination of the suspensorium in *A. macrodactylum*.

Ambystoma tigrinum is not directly comparable to any of the other five species. This is not due primarily to the size of the skull, but to a variety of differences which not only involve many particular bones, but also gross contours as well. The more apparent differences are:

1. The almost circular arc described by the premaxillae and maxillae.

2. The straight lateral border of the prefrontal, and the sharp angle it effects with the parietal. (In some species the relation posteriorly is with the frontal.)

3. A distinctive, hook-shaped process on the pterygoid.

4. A foramen dorsally on the parietal, for the exit of nerve IV.

5. The very triangular dorsal contour of the foramen magnum.

This species has such a wide distribution that possibly the description here covers a geographical type only. *A. tigrinum* also represents a dimorphic species, and this further complicates a study of its morphology. Despite all this, it is comparatively easy to segregate the species from the others in the genus because of the variety of differences the skull displays. It is expected that those which involve gross skull contours will be fairly constant in the separate individuals.

SKULL DIMENSIONS

Name	Greatest length of skull *Millimeters*	Smallest transverse diameter of brain case *Millimeters*
Ambystoma opacum	11	3⅛
Ambystoma tigrinum	17	5⅜
Ambystoma microstomum	8	3
Ambystoma talpoideum	10¾	4
Ambystoma maculatum	13	4½
Ambystoma macrodactylum	9½	3

Factors Affecting the Form of the Skulls

The adult cranium in amphibia, as in all higher vertebrates, is acquired by the addition of cartilage and dermal bones. The former (Wilder, 1923) "appear as centers of ossification within the cartilage of the primordial cranium itself, developing at those spots where either the strain of some other movable joint or that of some other mechanical force causes stress. Examples of these are the quadrate-articulare and skull-vertebral column articulations. In other words, their origin seems to be due to physiological reasons. Sometimes a cartilage bone serves to protect particularly delicate parts, as the prootic, which helps to form a cap about the otic capsule, and the orbito-sphenoid, which protects the exit of the optic nerve from the cranium." The dermal (skin) bones have no close relation to the primordial cranium but are closely applied, especially posteriorly, where the parietals and parasphenoid are seen to take the shape of the otic region. Because the

brain is contiguous with the vault here, one can conclude that it partially ordered the shape of the brain case in this region.

Perhaps the greatest single factor tending to modify the skull in all phases of development, is the musculature. Its coincident development with bone, and the formation of joints which permit the movements effected by it, suggest stresses which operate in the formation of the skull. Miner (1929) points out that "we know from the physiological processes involved in bone formation that the vertebrate skeleton is deposited in the interstices of the connective tissue network which also incloses the contractile cells. It is obvious that these skeletal deposits cannot exist where they would interfere with muscle action, and conversely they would occur in most highly developed condition where they would assist and strengthen that action. The areas of lost motion between opposing muscle groups would best answer that purpose, and it is in such intermuscular, fibrous regions of connective tissue that the fundamental internal bony or cartilaginous skeleton is found." A reference to the skulls illustrates that the more gross differences are found in the anterior and posterior regions, and that these are most directly involved in muscle and joint mechanics.

Another apparent feature of these skulls is the varying degree in which the bones approximate each other. This applies to paired bones as well as regions. The bones articulate with each other in two general planes, the longitudinal and the transverse. The greatest number of sutures are found in the longitudinal plane, whereas the transverse plane is characterized by two fused regions, the auditory-occipital and the vomero-palatine. It is to be remembered that the first parts of the skull to chondrify are the occipital and sphenoidal. This linear growth would favor fusion in the transverse plane, especially anteriorly and posteriorly, where the stresses due to developmental mechanics is most felt. The dorsal-posterior inclination of the vomero-palatine favors its fusion. This inclination varies in the separate species and might be a factor in explaining the condition of the internal nares and the space outlined by the mesial border of the bones. The constancy of the above characters has not been exactly determined.

It seems probable that the brain is secondary to the musculature as a factor in moulding the shape of the skull, due primarily to the general lack of proximity of brain to vault.

The cranial nerves, in their exit from the vault, create foramina that are sometimes distinctive. Blood vessels usually accompany the nerves.

The skeleton in general must reflect the degree of physiologic activity of a series of body systems and in particular the muscular. The impresses of these systems also suggest the sequence of their development. These stresses, further, have attained their status through definitely external stimuli, i. e., air, water, heat, moisture, cold, topography, local habitat, etc. The status of a particular system might be considered as the end result of chemical processes instituted by genes which can themselves be affected so as to alter these chemical reactions. Similarities between skulls such as that of *A. macrodactylum* and *A. microstomum,* and that of *A. opacum* and *A. maculatum* cannot be explained on the basis of geographical distribution. In the case of *A. tigrinum,* which is essentially dimorphic, and is distributed over almost all United States and the northern portion of the Mexican plateau, it is more reasonable to expect to find geographical types. The fact that in some localities the larval form is retained throughout life (Axolotl) points toward metamorphosis as a big causal factor in variations within this species.

In a comparative study of species in the genus, apparent differences involving *A. tigrinum* must be considered with caution. Specific characters and even generic characters apparently vary in this species. Cope (1887) explained individual variations on the basis of "variations in time and degree of metamorphosis, resulting in the partial retention of some larval characters." He rather considered metamorphosis as instituted and controlled at will by external factors, such as temperature, etc., with the result that he stressed geographical types to the extreme. Powers, in an extensive paper dealing with variations and its causes in this species, explains that some of Cope's most important geographical types were collected within a radius of six miles! This point is raised to emphasize the very plastic nature of *A. tigrinum.* Extensive experimental evidence produced by Powers (1907) shows that "the variations of *A. tigrinum* are primarily acquired variations of the larvae, that is, the direct or indirect result of environment during the larval lifetime. Some of the factors listed in the order of importance are (1) nutrition, (2) functional variations, use and disuse in varying degrees effecting changes." Powers concludes that "specific characters, in species which vary as *Ambystoma tigrinum* varies, are after all, strongly determined by environmental conditions. Congenital tendencies in such species are not definitely specific but only indefinitely specific." It was pointed out earlier that in this species they are not always definitely generic.

The problem in the genus *Ambystoma* seems to be to trace and properly classify ontogenetic forms such as result from the *A. tigrinum* species and to consider the phylogenetic significance of the others. Most of the variations pointed out by Powers are external and involve skin folds, muscle masses, fatty depositions, size of glands, etc., all of which are readily changed by such a factor as nutrition. Too little stress has been laid on comparative osteology in this genus, and particularly in this species.

Conclusion

The exact structure of the skull of salamanders is being used more and more to demonstrate genetic relationships. However, Noble (1921) points out that "fusion and losses of bones have occurred independently in many different genera and these are not always indicative of genetic relations." This fact was particularly recognized by other workers such as Cope, Fowler and Dunn. The question of whether a bone has fused with another or dropped out involves the problem of homology. It is stated on good authority that even in the single order Caudata, the cranial elements cannot be homologized with certainty, as contacts do not always determine homology. According to Noble (1921) "we cannot be certain of the homology of the anterior cranial elements of Rhyacotriton until the skull structure of the different short-toed species grouped under the genus *Ambystoma* have been investigated. After the crania of the species in the various genera of urodeles have been worked out, we will be in a position to compare the crania of closely related forms."

It is true that the old criteria of species determination are less effective as a result of recent advances in the fields of plant and animal cytology, physiology, and other correlated fields. This indefiniteness regarding the question of what constitutes a species is a good sign, as it is indicative of a more careful survey by scientists, of the interrelations of body systems and the interdependence of the various branches of biology. Skeletal studies are helpful because this system is especially susceptible to the impress of the other parts of the organism, especially the muscular, and this impress is open to direct observation.

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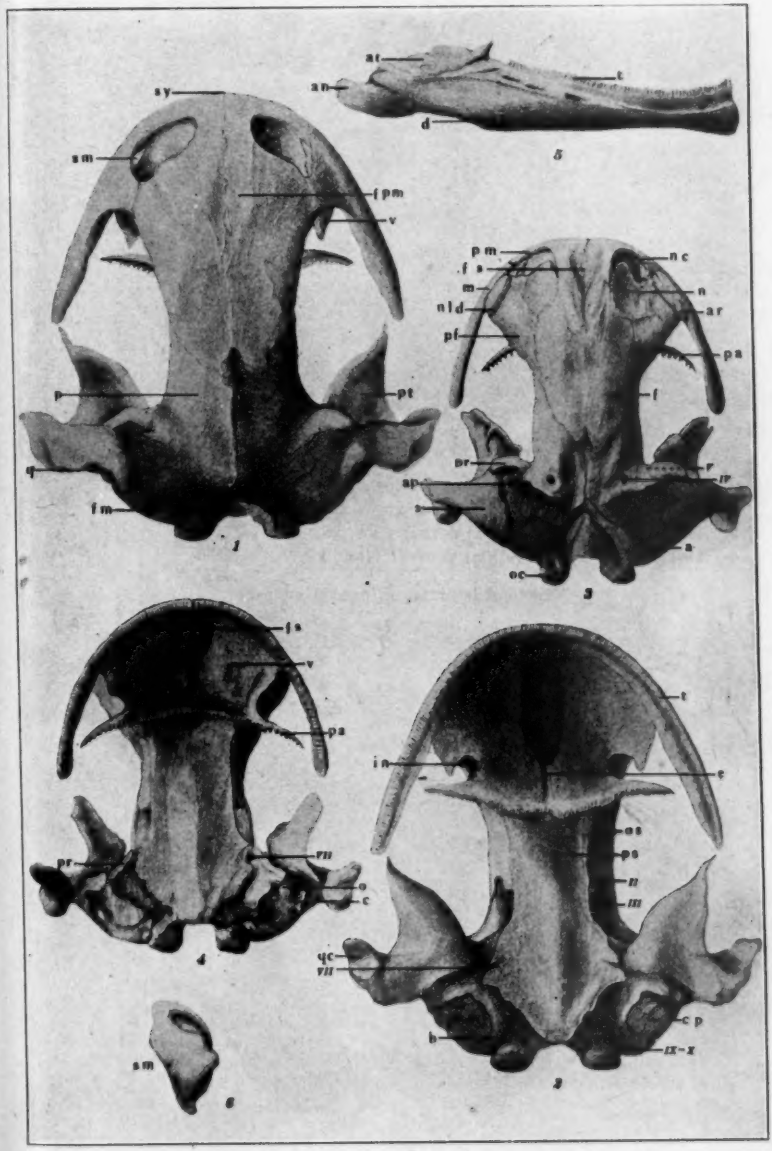
EXPLANATION OF FIGURES

1. Skull of *Ambystoma opacum*, dorsal view, x8.
2. Skull of *Ambystoma opacum*, ventral view, x8.
3. Skull of *Ambystoma tigrinum*, dorsal view, x4.
4. Skull of *Ambystoma tigrinum*, ventral view, x4.
5. Lateral view of lower jaw of *Ambystoma tigrinum*, semi-diagrammatic, x8.
6. The septomaxillary of *A. tigrinum*, dorsal view, x8.

LEGEND

a, fused auditory-occipital region
an, angulare
ap, angle of parietal
ar, ascending ramus of maxilla
at, articulare
b, bulla of auditory capsule
c, columella of stapes
cp, cartilaginous plug
e, extension of parasphenoid under vomero-palatine
f, frontal bone
fm, foramen magnum
fpm, frontal process of premaxilla
fs, fossa indicating former position of internasal cartilage
in, internal nares
m, maxilla
n, nasal
nc, nasal cavity
nld, superficial course of naso-lacrimal duct in prefrontal bone
o, operculum (of stapes)
oc, occipital condyles
os, orbito-sphenoid
p, parietal
pa, palatine portion of vomero-palatine
pf, prefrontal
pm, premaxilla
pr, prootic
ps, parasphenoid
pvp, posterior process of vomero-palatine
q, quadrate
qc, quadrate condyles
s, squamosal
sm, septomaxillary
sy, symphysis of premaxillae
t, teeth
v, vomero-palatine (fused vomer and palatine bones)
II, exit of optic nerve
III, exit of oculo-motor nerve
IV, exit of trochlear nerve
V, the dotted line indicates an anterior and mesial position of the exit of the trigeminal nerve
VII, partial exit of facial nerve.
IX, X, exit of the glossopharyngeal and vagus nerves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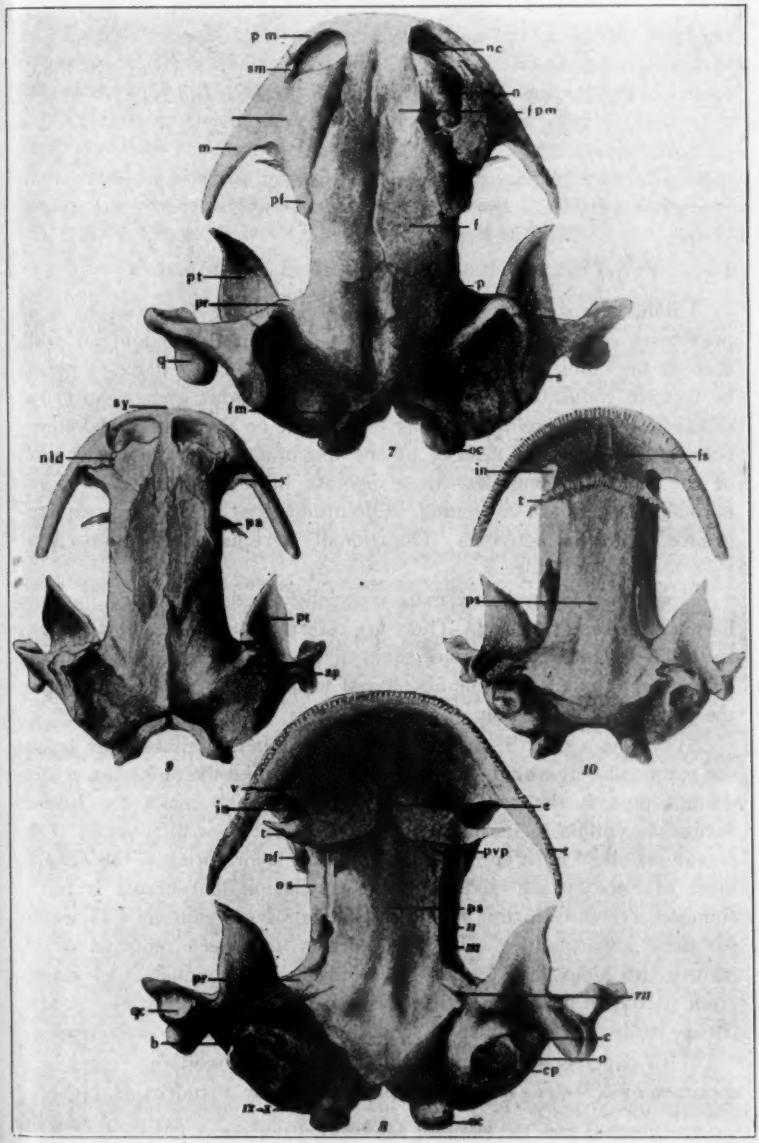
FIGS. 1-6

EXPLANATION OF FIGURES

7. ***Ambystoma talpoideum***, dorsal view, x8.
8. ***Ambystoma talpoideum***, ventral view, x8.
9. ***Ambystoma microstomum***, dorsal view, x8.
10. ***Ambystoma microstomum***, ventral view, x8.

(Legend is given on preceding page.)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FIGS. 7-10

HERNIA IN *NECTURUS MACULOSUS**

BY

WILLIAM F. HOHEISEL
University of Illinois, Urbana

INTRODUCTION

Man, because of his upright position and the fact that he is in possession of certain anatomical weak spots in the abdominal wall, such as the inguinal canals and umbilicus, is especially liable to hernia or rupture conditions. Heavy labor, overstrenuous games, bronchial diseases, and all activities tending to promote an increase in abdominal pressure through the descent of the diaphragm and the contraction of the abdominal muscles—these operate in the formation of some hernias. Others are congenital. Oftentimes they are not a great hindrance to normal activities. Occasionally serious complications arise as a result of stricture.

In higher forms below man, especially the dog, cases of inguinal hernia have been reported. These are referred to as rare. Quadrupeds have the advantage of a more equal distribution of the weight of the abdominal organs upon the abdominal wall, and so, less weight upon the weak inguinal region.

There is a dearth of recorded cases of hernia in animals below the mammals. It would seem that in a group like the amphibia, which do not possess the anatomical weaknesses which make the higher forms susceptible to hernia, this condition would be infrequent. Observations on Necturi specimens used in the laboratories of the department of Zoölogy are tending to the conclusion that hernia is fairly common, certainly in this species. Students were cautioned to watch for these abnormalities. To date, hernias have been reported which involve the lungs, liver, intestine, stomach, and oviduct. All stages from partial to complete hernia are represented in the series. A statistical study over a number of school years should prove interesting.

This paper is a description of three hernial conditions found in a specimen of *Necturus maculosus*, and reported by a student, E. Nebeck.

*Contributions from the Zoölogical Laboratory, University of Illinois, No. 411.

Description

Examination of the specimen disclosed a hernia of the liver and two separate areas of the intestines. The formalin used for preservation of the animals so hardened the tissues that it was possible to make perfect casts of the hernial sacs, and these represented the extruded portions of the organs which could be referred to their respective sacs in the abdominal wall. Only one hernia remained unreduced on discovery, the others having been disturbed through laboratory dissection, but from the casts their original condition was evident.

An oval area of the liver (about 2 centimeters by 1 centimeter) just anterior to the gall bladder, extruded through the abdomnial wall. The peritoneum, transversus and internal oblique muscles were involved in the order named. The rim of the hernial sac showed a thickening of the peritoneum, and also described the limit or remnant of this lining in the area involved. The internal oblique muscle, for the most part, formed the floor of the sac, although it was separated to the extent of 2 millimeters to receive a very restricted portion of the protruding liver. Through this separation, the fibres of the external oblique muscle were visible and demonstrated the furthermost progress of this hernia. The liver, through pressure, had apparently caused the atrophy of the fibres of the transversus muscle which are normally found external to the peritoneum. They were visible only as a roughened mass near the periphery of the sacculation. This condition, and that of the peritoneum, suggests that the rupture had been present for a long time. The perforation in the internal oblique muscle, on the other hand, suggests a more recent rupture. No atrophy through pressure is apparent. Dissections of the abdominal wall beyond the site of the hernia showed it to be otherwise normal.

The second hernia involved the intestine (about mid-way along the tract) and the abdominal wall on the right side at a point near the lateral edge of the rectus muscle. As in the first case, peritoneum and transversus muscle were perforated, but the internal oblique muscle alone formed the floor of the hernial sac. The sac permitted the displacement of a very small, evaginated area of the gut, which measured 2 by 4 millimeters in its greatest transverse diameters. The mass was constricted at the point of evagination so that it gave the appearance of a minute mushroom. Referring again to the hernial sac itself, the transversus muscle was seen to be separated definitely along the direction of its fibres, and did not present the frayed and irregular appearance described for the liver hernia. In general, the more limited nature, and the condition of the layers, suggest a fairly recent origin for this

hernia. Again, the site of the rupture (the lateral border of the rectus muscle) is a weak spot because the transversus muscle is limited in fibres here and ends in the thin peritoneum. Another mechanical factor is the laxity of peritoneum and transversus muscle in this region. A longitudinal section through the gut, made so as to include the evaginated part, showed no adhesions. The rugae extended into the stricture, but beyond this point the walls were thin and smooth. Histologic examination would be necessary to determine whether any modifications in the walls themselves had resulted from the condition. It is difficult to say whether the hernia reduced itself occasionally, but the dwarfed nature of the nearby ovary suggests that it did not. The respective positions of the root of the mesentary and the hernial sac were such as to prevent the normal distension of the ovary during the process of ovulation (ripening of eggs). The few mature eggs showed flattened surfaces and suggested that the gut exercised an abnormally constant pressure here. This might have been increased by periodic food congestions in the intestine, because of impaired movement due to the stricture. Another possible factor in this connection is the presence of another and more involved intestinal hernia on the opposite or right side. There is the possibility of course, that both hernias frequently reduced themselves, and that the pressure on the more ripened eggs, as evidenced by their surfaces, was brought about through pressure of the hardening tissues in death, and thro: gh formalin.

In the second intestinal hernia mentioned above, an entire loop of the gut entered a sac of which the internal oblique muscle was the floor and the peritoneum and transversus muscle were the lateral boundaries and rim. The intestine made a sharp "V" turn to leave the sac which was located in an area just behind, and lateral to, the posterior tip of the liver. It was directed forward and upward from a point near the lateral margin of the rectus to and beyond the lateral line, and this direction indicates the direction of displacement of the gut, about 4 centimeters of the latter being involved. That this hernia was acquired fairly early, was shown by the elimination of peritoneum and transversus muscle fibres (through pressure atrophy) along the direct line of progress of the hernia. Again, its location was in a region correspondingly stronger in muscle layers, that is, dorsally and laterally. It is recalled that the sac extends dorsally beyond the lateral line, and so really involves the epaxial group of muscles. One would assume that the ventral abdominal wall would be the most favorable for hernia since the greatest pressure due to the weight of the inclosed viscera would fall in that plane. Examination and dissection show that, generally, the transversus and peritoneum compose a sheet which is

relatively less contiguous to the whole muscle mass, or less firmly bound by fascia than are the external oblique, internal oblique, and rectus muscles. This condition would operate favorably for hernias induced early or late, since the trunk, in development, first acquires the capacity of muscle movement, followed by the fore limb and then the hind limb. Again, *Necturus* is peculiar in its development in showing metameric sacculations of the gut which might be homologized with the visceral (gill) pouches. In developmental stages, these sacculations have been found to extend from one end of the gut to the other. The question of the eventual fate of these in the adult brings up the possibility of other mechanical factors which strengthen the hypothesis of a developmental origin for many of the hernias in *Necturus maculosus*. Among the conditions which promote hernia in the adult, the weak linea alba or mid-ventral line might be added. This line is irregular, broad, and transparent when the skin is removed. Unlike the higher forms, it is composed of peritoneum (that has not been materially reinforced by the insertion of the transversus muscle) and a thin coating of fascia which spans the rectus muscles of the two sides. There is a general deficiency of fascial or aponeurotic sheets which ordinarily play such a strong rôle in the support of muscles in higher forms. The union of the various muscle layers through myocommata is insufficient. Most of the animals used in the laboratory were caught with a hook, and rough handling might be the cause of some ruptures, especially in the pharyngeal region. This is improbable for the cases described because they represent old hernias.

Conclusion

The hernias here described were apparently not a great hindrance to the animal's normal activities. The evidence from anatomy shows that they developed at different intervals. Certain factors favor the hypothesis of a developmental origin for them. However, the abdominal wall is especially weak in some regions and would favor the formation of hernias in the adult.

CORRELATION OF HOST PLANT AND COLOR PATTERN OF *RHODOBAENUS TREDECIMPUNCTATUS* (ILL.) (COLEOPTERA, RHYNCOPHORIDAE)*

BY

CARL MOHR

Illinois State Natural History Survey, Urbana

The cockelbur billbug, *Rhodobaenus tredecimpunctatus* (Ill.) varies strikingly in color from black with narrow red patches to red with small black spots. According to Blatchley and Leng (1916), and Weiss and Lott (1923), it occurs throughout the United States and feeds upon a host of plants, mostly composites. One variety, *quinquepunctatus* (Say), mainly black, is found on a species of thistle in southern states. Another variety, *pulchellus* (Shön) (fig. 1, D) is

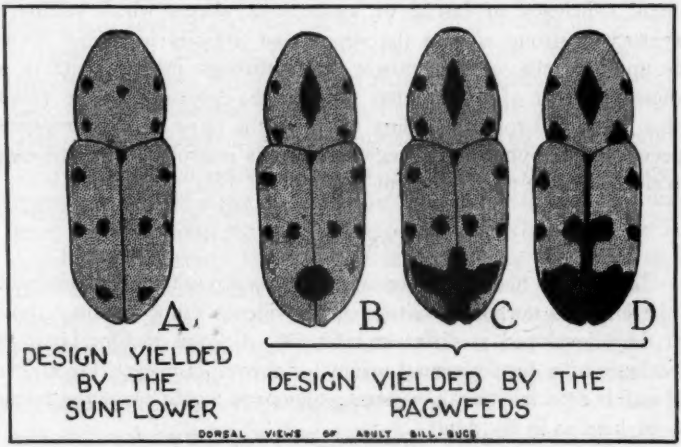

FIG. 1

common everywhere with the typical form *R. t. tredecimpunctatus* (fig. 1, A, B, and C). Observations of the writer indicate that color pattern of the adult may vary with host plant of the larva and that the varietal name, R. t. *pulchellus* (Schön), applied to individuals having the tip of the elytra entirely black, might well be dropped.

*Contributions from the Entomological Laboratories of the University of Illinois, No. 152.

Fifteen individuals were cut from their larval burrows in stalks of the sunflower, *Helianthus grossesserratus*, during the years 1928, 1929, and 1930. All are dorsally red with small rounded spots (fig. 1, A).

Twenty individuals were taken from their larval burrows in stalks of the giant and common ragweeds, *Ambrosia trifida* and *A. artemisiifolia* during the same years. They vary greatly in design as shown by figure 1, B, C, and D, but the median prothoracic spot is distinctly elongate, usually diamond-shaped, and the caudal spots on the elytra are fused. The figures show the extremes of variation.

It is evident that the varietal name *pulchellus* (Schön) implies a division where none exists, for every degree of intergradation is found between the forms illustrated in B, C, and D. If a distinct division of color pattern exists it is between the design yielded by the sunflowers and that yielded by ragweeds as a group, but the possibility that the many larval hosts determine adult designs makes obvious experiments more profitable than the shifting of names.

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STATISTICAL ANALYSIS OF QUANTITATIVE COLLECTIONS AS A MEANS OF INTERPRETING LIFE HISTORIES*

BY

HARLEY J. VAN CLEAVE

University of Illinois, Urbana

INTRODUCTION

There are relatively few species of animals whose entire life history is known. The developmental cycles of even some of the species most commonly used for study in zoölogical laboratories have been but imperfectly traced or have been unstudied. The concept of specific life histories has not been given serious consideration by the present generation of scientists. The closing decades of the nineteenth century witnessed a revival of interest in the process of cleavage and in the early stages of embryonic or larval development because of the dominating interest in the problems of cell lineage and of experimental embryology, but this interest rarely inspired an investigation of the complete life cycle. Exception may be raised to this generalization in the case of animals of distinct economic importance. The result is that we have fairly complete pictures of the successive seasonal changes of many of the economic insects and ticks and know with a fair degree of precision the cyclic periods in the life histories of parasitic worms and protozoa which are causal agents of disease in man and other animals, but beyond these fields of investigations there has been but little progress in the interpretation of individual life histories. In part, this static condition may be traced to an unwarranted assumption that closely related forms have identical life histories. A like assumption of essential similarity invalidated many of the early researches in other fields of biological inquiry. Many of the early investigations on physiology of the invertebrates, as well as those dealing with reactions, experimental embryology, and regeneration, gave erroneous results because of the erroneous assumption that members of a given genus or other large systematic unit have identical physiological responses. In the field of experimental zoölogy, this error has been recognized and only individuals of the same species or variety, and preferably members

*Contributions from the Zoölogical Laboratory, University of Illinois, No. 408.

from the same sort of habitat, are used in experiments that are expected to yield specific results.

In the literature on life cycles the concept of specificity of development has not yet been widely accepted. Perhaps the morphological "type" concept which dominated the zoölogical thinking of a generation ago has lingered in the minds of zoölogists who have written on topics concerning individual development. To the person whose morphological thinking permits of a non-specific generalized concept of *"the* frog" or *"the* crayfish" the inadequacy of a generalized scheme of ontogeny may not be apparent, but to the person who has collected and studied animals in the field, such generalized type concepts have little meaning, for he observes differences in structure, in habits, in reactions, and in seasonal occurrence, all of which can be explained only by underlying physiological differences. These physiological differences in turn became reflected in specific differences in development, leading to specifically recognizable life cycles.

Methods of Interpretation

Two methods have been very generally relied upon for securing data upon the life history of animals. The more important and more trustworthy of these is that of direct field observation, following the animal in its natural habitat throughout all seasons of the year. By this method, growth, transformation from one stage to another, changes in habits and in habitat, are directly observed so that a specific calendar may be prepared to record the changes in form and activity of each species under observation.

The second method is that of experimental determination of the life cycles. By this method, the animal being studied is brought into the laboratory where observations may be more easily made. Under the experimental method great discrepancies are apt to intrude due to lack of complete duplication of the natural habitat. Even under the most carefully checked laboratory conditions, it is impossible to recreate natural conditions for any but a very few organisms. Checks on animals kept under the most carefully guarded conditions frequently yield evidences of significant departures from conditions shown by controls under natural surroundings. Observations based upon animals kept under experimental conditions are never acceptable unless in agreement with controls in the natural habitat. There are numerous investigations setting forth the results of experiments designed to show the influence of relative numbers of individuals reared in a given space upon the size of the individuals. The physiological significance of

these experiments must not be overlooked by any student rearing organisms in cultures for studies on the life cycles.

A third method of securing data on certain aspects of specific life histories is through the analysis of quantitative seasonal collections. This avenue to an understanding of life cycles has been relatively little used, and its possibilities have never been exhausted. Investigations that have been completed and others still in progress in the Zoölogical Laboratory of the University of Illinois give ample evidence of the value of detailed studies of quantitative collections as a supplement to field observations. The value of periodic collections becomes especially evident in studying animals from habitats that are at inconvenient distances from the laboratory.

The only limitation to the applications of this method of investigation is that of relative abundance of the organism under investigation. The method has been applied to amphibians, reptiles, fishes, crustaceans, and molluscs, and has untried possibilities in practically all of the other invertebrate groups.

Seasonal growth rate, determination of actual or relative age, ratio of the sexes, correlation of sex and size, development of secondary sexual characters, reproductive habits, seasonal limitations to growth and reproduction, changes in body form, periodic changes in habitat, are but a few of the many topics which may be investigated upon preserved quantitative materials brought from the field into the laboratory for uninterrupted analysis. Naturally, this method of analysis has its greatest value when checked by extended field observation. In turn, both field study and analysis of quantitative data are profitably directed by the observations on animals kept under experimental conditions. Thus, the minute eggs of a snail belonging to the species *Goniobasis livescens* were first observed in laboratory aquaria (Jewell, 1931), and this observation led later to their detection in the native habitat after periodic collections had demonstrated the onset of the gravid conditions in the females brought directly from the stream. Similarly, in the viviparous snails the state of development of the females in quantitative samples gives a clue to the breeding season and provides information as to the season when young are born (Lederer in unpublished thesis).

In 1916, the writer utilized seasonal collections of Acanthocephala for the interpretation of life history data. For three species of the family Neoechinorhynchidae he showed marked specific differences in periods during which these parasites dwell in the intestine of their vertebrate hosts. Two species living in the same host species were found to have entirely different seasonal periods of infestation. Either periodic changes in food habits of the final host or essential develop-

ment phases of the life cycle of the parasite in the invertebrate host might be responsible for such an instance of seasonal restrictions to the occurrence of the parasites within their normal host. In the same paper, the author called attention to the fact that another species of Acanthocephala *(Neoechinorhynchus emydis)* occurs in turtles throughout the year. Individuals of this species seem to have residence in the turtle for at least a year, hence the occurrence of young and old individuals at all seasons led to the conclusion that reinfestation is continuous, not cyclic. In the course of this study on life histories of parasitic animals by analysis of periodic collections, it was found that unselected data on negative records may lead to an erroneous interpretation of cyclic occurrence, for negative records frequently indicate the total absence of a parasite in a given region rather than reflect a seasonal absence from the host.

Particularly significant life history studies on marine organisms have been conducted by British investigators working at the Plymouth Laboratory. In many of the studies that have come from that laboratory, the statistical method of interpretation has played a most important part. The researches of J. H. Orton (1928) on the oyster and the heart shell (1926) are admirable examples of life history investigations as are also those of E. W. Sexton (1924) on Gammarus and of A. C. Stephen (1929) on Tellina from the same laboratory.

Observations and conclusions derived from recapture of marked individuals have played important rôles in the study of fishes, especially the salmon, and the same method is now being widely practiced with gratifying results in the cooperative study of banded birds.

In recent years, investigators in the United States Bureau of Fisheries have made marked progress in life history investigations through an analysis of periodic collections and a combination of this method with field observations and analysis of statistical data, but space forbids an enumeration of more than a few typical references. Rich (1925) has given a summary of the studies on age and maturity of the chinook salmon. Van Oosten (1929) has completed an intensive study of the life history of the lake herring. Schroeder (1930) has assembled a great amount of information on the life history of the cod.

Other investigators working for the Bureau of Fisheries have brought forth significant results in the study of Mollusca, determining age, rate of growth, relative abundance, and reproductive habits. Characteristic of these recent contributions may be mentioned the work of Gutsell (1931) on the bay scallop and that of Weymouth and McMillin (1931) on the razor clam. A new activity in the investigation of fresh-

water mussels is reflected in publications of Isely (1914) and of Chamberlain (1931) on the growth of mussels.

In many of the older biometric studies, populations of a given species of animal were measured and a normal distribution or growth curve was obtained. Occasionally, populations gave a bimodal or polymodal curve because of extreme differences in size of the sexes or segregation of age groups. In the early investigations most of such statistical analysis was made upon assemblages of individuals without regard to date of collections. The chief contribution of such a study, in fact the only end sought by many students, was the establishing of size range of the species. When seasonal collections are considered individually, they frequently yield much biological information of value. Thus, in the fishes, relative age and sex have both been found significant factors for consideration in further resolving a simple curve showing distribution in a population according to size (Van Cleave and Markus, 1929, figs. 1-3).

A series of distribution curves based upon collections made at stated intervals gives a graphic picture of rate of growth in the entire population through the progressive shifting of the modes of the population. Thus in a series of twelve monthly collections of a species of fingernail shells belonging to the genus Sphaerium, Foster in an unpublished thesis has been able to give a very satisfying picture of rate of growth, to determine the length of life of the individuals of this species, and to ascertain precisely the dates when young are being produced.

Similarly, in some species the occurrence of gravid females at all seasons of the year gives rise to the impression that the species continues to breed uniformly throughout the year. Thus, in the isopod *Mancasellus macrourus,* Markus (1930:232) found gravid females throughout the year, but a statistical analysis of his data (Markus 1930, fig. 4) revealed the fact that less than 5 per cent of mature females were carrying eggs or young through the fall and winter (September to February) while more than 50 per cent of the females taken in April carried either eggs or young. He further found a significate correlation (p. 231) between the season of the year and the number of young produced by each female.

F. N. Blanchard (1928 and 1931) has skillfully applied the statistical method in an analysis of many aspects of the life cycle of salamanders. Other similar, isolated instances of application of this method might be cited, but it is the purpose of this paper to call attention to new lines of investigation by this method rather than review the entire literature.

Morphological characters that have been considered as specific and have been used for the separation of species are interpreted in new light when studied in quantitative collections. Thus in the isopods, the number of antennal segments has been considered as a specific character (Richardson 1905:413) although Markus (1930:224) by following the growth of individuals in quantitative samples through the year has been able to correlate number of antennal segments with age through relation of segment number to the number of ecdyses.

Investigations are under way on the life cycles of a number of species of invertebrates, the extent of whose life spans has never before been determined. For several of these species it has been found that individuals of the maximum size group are wholly lacking in the quantitative samples taken during certain periods of the year. This fact indicates that these individuals have a life span of less than a year. If it took more than a year for the individuals to reach maximum size there would always be individuals of the maximum size group present in every population. In case the breeding season is restricted to a definite month, age groups when plotted would tend to fall into well defined modes, one mode for each year group.

In some groups of animals which have a sharply limited growing season and a breeding season of considerable length, size groups even if they are composed of members of the same sex do not always represent a single age group. Thus in one of the minnows it was found (Van Cleave and Markus, 1929) that some individuals hatched late in one breeding season are no larger than those hatched early in the following year, after both groups have passed through a single growing season. Many of the fresh-water fishes furnish especially favorable material for quantitative study of growth and the whole life cycle, for although the restricted growing season adds some confusion to the size groupings, composite groups of varying age are rather easily resolved into age groups by microscopic examination of the scales.

In some extraordinary instances, abnormal individuals may result from disturbed metabolism and hence may introduce elements of complication into a statistical analysis of quantitative samples. Among the vertebrates, cannibalism may lead to a type of gigantism. Such abnormalities must be considered thus and cannot be considered in the analysis of populations where normal growth is assumed.

The foregoing are but a few of the numerous instances that might be cited showing wherein an analysis of quantitative collections yields valued results in the interpretation of life cycles. The method, although by no means new, deserves more attention as a tool for the unwinding of complicated life histories than it has been accorded in the past.

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GRAPE COLASPIS AS A CORN PEST IN ILLINOIS*

BY

J. H. BIGGER

Illinois Natural History Survey, Urbana

GENERAL STATEMENT

The Grape Colaspis, *Colaspis brunnea* (Fab.) is one of the corn pests which regularly does a small amount of damage but which occasionally appears in outbreak form in central Illinois, causing severe losses to the corn crop. It was reported by S. A. Forbes [4] in an outbreak in western Illinois in 1900, and was noted by the author in 1924-1926. The latter outbreak seems to have been the most important recorded in the State up to the present time, and was the cause of the observations here reported. Losses were first reported in many of the western counties during the early part of the outbreak, but it later developed into a serious corn pest throughout the central part of the State. In 1926 at least two thousand acres of corn were totally destroyed and many more were damaged.

FOOD PLANTS

The adults of the Grape Colaspis have been observed to feed on red clover, corn, timothy, alsike clover, soybeans, alfalfa, swamp smartweed, bull nettle, grape leaves, strawberries, and apples. The larvae have been taken on the roots of red clover, alsike clover, sweet clover, soybeans, timothy, corn, and strawberries. The insect is also reported [3] as feeding on potatoes, beans, watermelon, okra, roses, plums, pears, wild hop, willow, and Virginia creeper. The adults hide at the bases of the plants during the night and feed during the daytime.

PRELIMINARY OBSERVATIONS.

Several reports of damage were received in 1924 and were investigated. When damage was reported again in 1925 a survey was made to determine any important factors which might appear and the survey was repeated in 1926.

Briefly, the results of these surveys indicated that the most severe damage occurred in corn planted on land where red clover had been

*Contribution from Illinois Natural History Survey Project 8.3.

plowed under, and, further, that the bulk of the losses were in fields that had been plowed late in the spring just before the corn was planted. Some losses occurred where soybeans had been grown in the same field for a period of years in succession. The result of the surveys led to a more detailed study of the life and possible control measures for the pest. This study was started during the summer and fall of 1926.

Life History and Descriptions

A general life history study was made but only a few details were determined.

Adult. The adult is a yellowish-brown or straw-colored beetle about one-fifth inch long, oval, rather convex, the wing covers marked with alternate ridges and depressed lines or rows of small punctures. Collections are reported by Forbes [4], mostly from southern Illinois, from June 22 to September 15, and by the present author from June 19 to August 29. During this time they are most abundant in red clover fields, although they are found on a number of plants as stated above.

Egg. As far as can be determined the eggs have not yet been found or described. Attempts by the present author to obtain eggs from beetles in captivity were unsuccessful. From our observations and knowledge of the habits of the beetles we presume that the eggs are laid on or around the bases of the food plants during the latter part of July and during August. These eggs probably begin hatching during the first half of September.

Larvae. The larvae are small, grub-like, about three-sixteenths inch long when full-grown. They are grayish-white or a distinctive very light tan color, with a brown head and neck-shield. The legless segments each bear a pair of fleshy appendages tipped with two or three short hairs. The authors earliest finding of the larvae was September 20, 1928, when they were about one-sixteenth inch long; the latest finding was July 1, 1926. The earliest and latest reports available are in unpublished notes by Forbes, in which the larvae were shown to be present September 13, 1883 and July 9, 1883 at Anna, Illinois. The larvae are slow-growing and live about nine months.

Pupae. The pupae of the Grape Colaspis are about one-eighth inch long and white in color. As they near maturity the eyes turn red and the mandibles black. At the posterior end of the abdomen are two incurved hooks with a large backward-directed spine just anterior to each. Pupation takes place in small oval cells two to three inches deep in the soil, usually about six inches from the base of the food

plant, and requires about two to three weeks. Pupae were first found June 5, 1922. Pupae were found June 16 and adults emerging June 30, 1925.

Hibernation. It has been shown [1] that the insect hibernates as a larva. Early in the season these are found close to the soil surface. During the latter part of October or first part of November in this

FIG. 1. *(Above)* Corn injured by Grape Colaspis—Note missing and withered hills. Planted on red clover land plowed in late spring. (Near Lynnville, July 21, 1926.)

FIG. 2. *(Below)* At the right, corn on red clover land plowed in late spring; at the left, corn on red clover land plowed in late fall. (Near Lynnville, July 21, 1926.)

latitude they start downward in the soil, and by the latter part of November 60 to 70 per cent of them are eight to ten inches deep, and considerable numbers are found as much as twelve inches below the surface. They remain here until the last part of April the following spring. Larvae were found May 4, 1927, returning to the surface.

Type and Extent of Damage

The adults eat small oval holes through the leaves, frequently linked together to make larger holes. These may sometimes be so numerous as to skeletonize the leaf, but adult feeding does not often cause serious damage in Illinois.

The larvae feed on the surface of the roots. They may remove the surface in a ring entirely around the root, or they may eat out narrow strips lengthwise of the root. This removes the root hairs and causes the plant to starve.

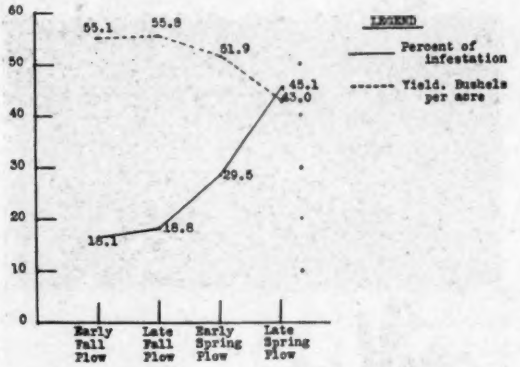


Fig. 3. Graph showing relation between yield of corn and infestation by grape colaspis.

During the 1926 season the larvae in many fields destroyed 30 to 40 per cent of the plants. A number of records show 60 to 70 per cent of the plants destroyed and in one field 78 per cent of the plants were rendered worthless. In one eighteen acre field it was necessary to replant seventeen acres. In the one remaining acre the clover in the field had been killed the previous year. (See figs. 1 and 2.)

Control

Two lines of control are made available by the investigations carried on during 1926-1929, namely (a) adjustment of the rotation, and (b) timely plowing of sod land where corn is to be planted.

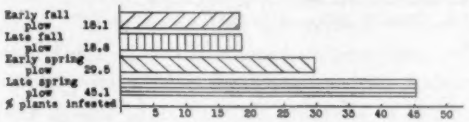
Investigations made as a part of the life history studies show that the larvae are most numerous in second-year red clover sod and are less numerous in other types of grass and legume sods. There are some numbers in second-year sweet clover sod, but this crop will ordinarily be plowed under in a manner that will act as a control

measure. When sweet clover is used as a soil-building crop it is generally plowed under at the end of the first year. The following table [1] shows the results obtained in digging cubic-foot areas in the types of cover listed and indicates that the use of sweet clover or soybeans to replace red clover as a soil-building crop would greatly reduce the necessity of supplementary control measures.

TABLE I

NUMBERS OF LARVAE OF *Colaspis brunnea* IN SOIL AT ROOTS OF VARIOUS CROPS

Crop	Number Diggings	Number Fields	Number Larvae Found	Number Larvae per cu. ft.	Maximum	Minimum
2nd year red clover.....	8	2	264	33.0	67	16
1st year red clover.....	6	2	4	.66	2	2
2nd year sweet clover....	4	2	42	10.5	16	5
1st year sweet clover.....	3	2	16	5.33	6	4
Soybeans	8	3	1	.12	1	0
Timothy	5	2	4	.8	2	0



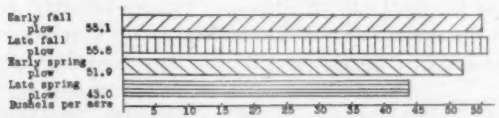

Early fall plow 53.1
Late fall plow 55.8
Early spring plow 51.9
Late spring plow 43.0
Bushels per acre
5 10 15 20 25 30 35 40 45 50 55

FIG. 4. *(Above)* **Graph showing percentage of plants infested by grape Colaspis (average of three years experiments).**

FIG. 5. *(Below)* **Graph showing yield of corn from plots infested with grape colaspis (average of three years experiments).**

The attempt to control Grape Colaspis in red clover sod took the form of experiments to determine the effect of plowing at different dates. These tests were made on farms in Morgan County all within a mile of the station of Arnold, Illinois. Portions of the red clover sod were plowed at different times mid-September, early November, early April, and late April or early May just previous to corn planting. The plots were duplicated in the field in each case. The corn was planted on the plots at the same time and otherwise handled in the usual manner. In early June of each year two hundred hills were dug from each plot and the roots and surrounding soil were carefully examined for the presence of larvae or pupae. In the fall typical samples were harvested from each plot and the yields recorded. This experi-

ment was repeated for three successive years. None of these was a year of heavy infestation.

The graphs (figs. 3, 4, and 5) show the results of the experiments. The figures are the average of all records for each plot for the three year period.

Lack of space prevents showing the records for each year, but these all correspond quite closely with the average results shown. In all cases the fall and early-spring plowings showed the least numbers of larvae present and the highest yields of corn on the plots.

It has been stated [5] that spraying the food plants of the adults would control the adult population.

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SOME OBSERVATIONS ON THE HERMAPHRODITE APPARATUS OF *VALVATA TRICARINATA* (SAY)*

BY

C. L. FURROW

Knox College and University of Iowa

These observations have been made as a part of a larger study on the problem of development and differentiation of the ovo-testis of the fresh-water prosobranchiate, *Valvata tricarinata* (Say). It has been pointed out in an earlier report [5] that dimorphic spermatozoa are formed during the normal functional activity of the ovo-testis. In studying the development of these dimorphic spermatozoa, many interesting observations on the more general biological aspects of the animal have been made. The material used was collected from Lake Okoboji in northwestern Iowa. The preliminary observations and early stages of the work were carried on in the Iowa Lakeside Laboratory.

The writer desires to express his gratitude to Dr. E. Witschi for his valuable counsel and to the Committee for Research in Problems of Sex of the National Research Council for the financial aid in carrying on this problem. Professor Frank Collins Baker has aided in identification of the material and has offered suggestions relating to the anatomy of the animal.

This problem involves the use of living and fixed material. Dissections were used for the study of the anatomical elements. Other material was preserved for the study of the histological and cytological aspects of the problem. Some smears were prepared but they have not contributed to the analysis of the problem, largely due to the presence of abundant large yolk spheres and granules which were liberated from the developing eggs and to pigment bodies from the capsular covering of the ovo-testis which obscured the details of the smears. Satisfactory results have been obtained from material prepared in Zenker's Solution, Bouin's picro-formol-acetic mixture, Allen's modification of Bouin's Fluid, Gilson's fixation modified according to Petrunkewitsch, Hermann's Fluid, Helly's Solution, and Burckhardt's Fluid.

Flemming has been the least satisfactory as a fixation. Sections were stained in Heidenhain's iron-haematoxylin, with and without

*Contribution No. 38 from the Biological Laboratories of Knox College and of the Zoological Laboratories of the University of Iowa, aided by a grant of the Committee for Research in Problems of Sex of the National Research Council.

eosin as a counter stain; some were stained in Delafield's haematoxylin and counterstained with Congo Red and Orange G. Mallory's "Triple" stain was used with good results for the supportive elements. Iron-haematoxylin followed by a mixture of gentian violet and erythrosin has proved useful in many instances.

Valvata tricarinata is a small fresh-water streptoneuran prosobranchiate gastropod with a sharply carinated spiral shell about four millimeters in diameter. The animal possesses a large foot which is bluntly rounded posteriorly and bears two anterior filament-like lobes. Sessile eyes are located at the base of long cylindrical tentacles. Valvata possesses external gills. The gills are external; the left is plumose and extends backward over the shell as the snail moves through the water—the right is a rudimentary structure forming a slender appendage which protrudes from the shell when the animal is extended [3].

The animal is hermaphroditic. The reproductive system is composed of a single ovo-testis with a single hermaphrodite duct leading to a seminal vesicle; a continuation of the duct after it is joined by the duct from the prostata becomes the vas deferens and finally terminates in the pyriform penis. The female aperture is situated on the right side between the right gill and the anus. A short vestibule which bears the female aperture receives the oviduct from the spermatheca or seminal vesicle (also called Bursa copulatrix), the duct from the albumen gland, and the duct from the large crescent-shaped accessory shell gland [4].

The breeding season in Lake Okoboji begins usually in March and continues until late in August. The eggs are small oval structures (fig. 2) sharply pointed at each end and are about 0.25 by 0.37 millimeter in size. Four to eighteen (Table I) elliptical eggs are deposited at one time in small globose albuminous capsules (fig. 1) which are greenish in color. In the natural environment the egg capsules were observed attached to aquatic plants (*Potamageton sp.*, and *Sagittaria* sp.), to floating objects, and to the shells of other Valvatae. In the laboratory the egg capsules were found attached to the sides of the glass aquaria. Development is completed under conditions of the laboratory in twelve to fifteen days. The young Valvatae are very active and were observed moving rapidly over the sides of the aquaria and were often found oriented to the surface film of water with their shells hanging downward. Some of the young animals were removed from the stock aquaria and transferred to smaller aquaria jars. Small leaves of fresh lettuce and occasionally small amounts of spirogyra were added to the aquaria as food. Water was added to compensate for

evaporation. Under conditions of laboratory environment young Valvatae which emerged from the egg capsules on July fifteenth attained their maximum adult shell-size of about four millimeters about the first of the following November. At the present stage of the study nothing is known concerning the sexual cycle or the duration of the life span of *Valvata tricarinata.*

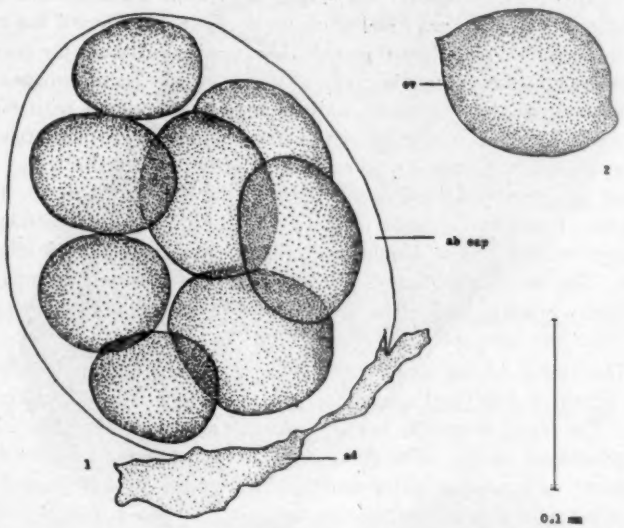

Fig. 1. A camera lucida sketch of an albuminous egg capsule containing eight eggs. Magnification x 80.

Fig. 2. Sketch of one of the eggs from the above capsule. Magnification x 80.

In Valvata the hermaphrodite gland, the ovo-testis, occupies the last whorl of the shell. The gland is smooth, non-lobated, conforms to the cavity of the shell, and is made conspicuous by its dense black color due to the pigmentation of the thin outer capsule. The cells composing the covering of the ovo-testis are heavily laden with large dense black pigment bodies which impart a black color to the gland. The proximal portion of the ovo-testis is embedded in the liver tissue. The distal portion terminates freely in the cavity of the apical whorl of the shell. The hermaphrodite duct lies on the columellar side of the gland within the capsular covering of the ovo-testis where it receives the outlets of numerous atria of the acini. The hermaphrodite duct leads finally to the seminal vesicle.

The ovo-testis of the sexually mature Valvata is a compact structure embedded in the liver. A thin, darkly pigmented layer (Plate, fig. 1) covers the entire gland. This supportive layer which is three to four cells thick is made up of flattened cells with prominent nuclei. Dark pigment granules fill the cytoplasm of the cells of this capsular layer.

In the adult ovo-testis the female and male elements are quite loosly separated—the eggs and ovocytes are oriented toward the outer region of the crescent-shaped gonad. The acini which bear the spermic tissues occupy the columellar region of the gland. In this manner of arrangement of the ovo-testis, Valvata may be compared with higher forms which exhibit in the indifferent stages a definite cortical (female) and a medullary (male) region. Parenchyma forms the loose supportive structure which loosely delimits the female elements from the acini (Plate, fig. 3). The acinus is made especially conspicuous by its large inflated lumen which is usually filled with fluid and spermatozoa. The acini are compressed frequently into irregular forms by the rapidly growing eggs. The atria (Plate, fig. 3) serve to connect the acini with the hermaphrodite duct.

The lining of the acinus is composed of epithelium, indifferent cells, nutritive cells, and spermatogonia in various stages of development. The lining is usually very thin and is made up of flattened cells with prominent nuclei. The germ cells showing a definite regional arrangement within the acinus-gonial stages form one cyst, cells in division form another, spermatocytes in the first maturation stages a third cyst, spermatids another, and ripe spermatozoa are likewise contained in another separate cyst.

EXPLANATION OF PLATE

Fig. 1. Photomicrograph of a section of the ovo-testis cut parallel to the columellar axis. It shows the peripheral arrangement of the eggs and female elements. Magnification x 111.

Fig. 2. Section through the hermaphrodite duct during the discharge phase. The duct contains ripe spermatozoa. Magnification x 170.

Fig. 3. Section of the apical end of the ovo-testis cut at right angles to the columellar axis. The apical end shows the differentiating female components. Magnification x 112.

LEGEND

ab cap = albuminous capsule
ac=acinus
ad=adhesive disc of capsule
at=atrium
go=young egg cell in growth stage
hd=hermaphrodite duct
la=lumen of acinus
lv=liver
oc=young ovocyte
ov=egg cell
pc=pigmented capsule of ovo-testis
sp=cyst of spermatoza
st=supportive (parenchyma) tissue

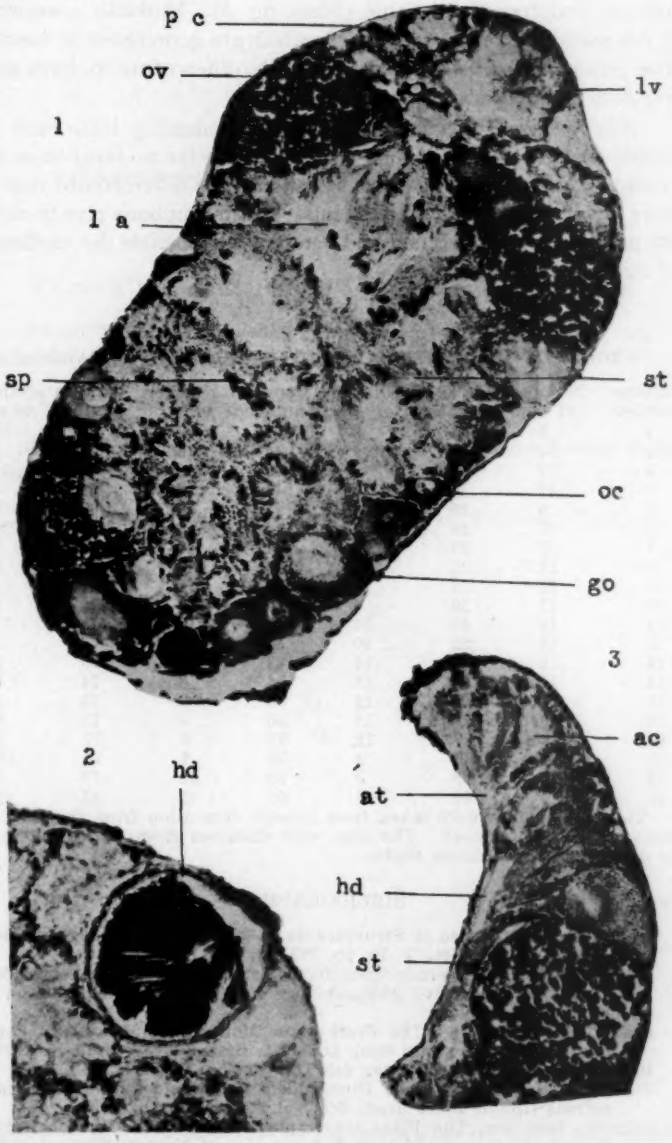

PLATE I

The apical or terminal portion of the ovo-testis is made up of a mass of undifferentiated tissue (Plate, fig. 3). Markedly conspicuous in this mass of parenchyma are cells which are germinative in function. The germinative cells multiply and finally differentiate to form nutritive cells and primary ovogonia.

The ovo-testis is, although a gland containing both male and female sexual elements, a dual structure in-so-far as function is concerned. The female components seem to be less differentiated than the more highly specialized male elements. It is the author's plan to extend the problem in this direction and determine if possible the mechanism of this differentiation.

TABLE I

NUMBER OF EGGS PER CAPSULE IN VALVATA TRICARINATA

Capsule number	Number of eggs	Capsule number	Number of eggs	Capsule number	Number of eggs	Capsule number	Number of eggs
1	8	21	8	41	7	61	12
2	17	22	9	42	13	62	9
3	17	23	9	43	6	63	13
4	12	24	7	44	8	64	8
5	9	25	16	45	10	65	9
6	11	26	7	46	8	66	10
7	12	27	12	47	7	67	9
8	11	28	8	48	7	68	6
9	12	29	14	49	4	69	11
10	12	30	6	50	8	70	8
11	16	31	14	51	10	71	14
12	18	32	10	52	12	72	8
13	9	33	13	53	7	73	8
14	12	34	15	54	8	74	6
15	6	35	12	55	9	75	7
16	10	36	11	56	4	76	8
17	8	37	11	57	8	77	9
18	12	38	9	58	8	78	10
19	11	39	9	59	11	79	8
20	10	40	13	60	10	80	12

The egg capsules were taken from aquatic vegetation from the lake and removed to the laboratory. The eggs were dissected from the capsules and the data recorded as shown above.

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PAPERS IN PHYSICS AND CHEMISTRY

EXTRACT FROM THE REPORT OF THE SECTION CHAIRMAN

All of the papers published herewith were presented at the meeting of the Section on Physics and Chemistry.

The maximum attendance was about 75.

Mr. C. L. Cross, State Normal University, Normal, was elected chairman of the section for 1931-1932.*

(Signed) JAMES H. RANSOM, *Chairman.*

* Mr. C. L. Cross resigned from the chairmanship and the Council later appointed Mr. Elmer H. Williamson, Department of Physics, University of Illinois, as chairman for the 1932 meeting.

NON-AQUEOUS SOLVENTS AS MEDIA FOR CHEMICAL REACTIONS

BY

L. F. AUDRIETH, R. E. MEINTS and E. E. JUKKOLA

University of Illinois, Urbana.

Chemists have become so accustomed to the idea of water as the universal solvent that it may seem almost unbelievable that other media may be used effectively for carrying out chemical reactions. There is no question but that our slavish devotion to water as the medium for chemical reactions has obscured much important chemistry and has somewhat retarded the advance of our knowledge along certain lines. During the last few years such solvents as liquid ammonia, hydrogen fluoride, glacial acetic acid, the alcohols, and many others have been studied by numerous investigators. These researches have brought to light not only many new and interesting facts, but they have shown very definitely that in some instances it is of decided advantage to use solvents other than water.

The writers of this paper have been interested in the use of non-aqueous solvents in a variety of reactions. The experimental results summarized briefly in the following paragraphs give ample proof of the applicability of non-aqueous solvents to specific problems and for special reactions which could not have been carried out in water.

Electrodeposition of Arsenic, Antimony, and Bismuth from Solutions of their Salts in Glacial Acetic Acid.—The chlorides of these three fifth-group elements are characterized by their high solubility in anhydrous acetic acid, and by the fact that they undergo no solvolysis in this medium, because of the *acidic* nature of the solvent. In water, on the other hand, these chlorides undergo hydrolysis with the precipitation of basic compounds. Electrolysis of acetic acid solutions of these substances under varying conditions of concentration, temperature, and current density results in the cathodic deposition of these metals.

Preliminary results led to the hope that a method might be worked out for plating objects with antimony. Antimony is very resistant to corrosion by hydrochloric acid, and antimony plated apparatus would find wide application in industry. The metal is, however, characterized by its brittleness under ordinary conditions which means that it must

be deposited in a very finely crystalline form and must be prevented from changing to a more coarsely crystalline state.

The original deposits on copper and brass were smooth and adherent, but were found after a time to scale off and break when sample plates were subjected to stresses and strains. X-ray investigations of these deposits by Dr. C. W. Stillwell brought out the fact that an unstable, monotropic, amorphous form of the metal was deposited under ordinary conditions which tended to revert to the more stable crystalline form. Investigation of arsenic deposits showed that these, too, were plated out in the amorphous state, whereas bismuth was found to come out in the crystalline form. This problem is still under investigation.

Preparation of Rare Earth Metal Amalgams by Electrolysis of Solutions of the Halides in Absolute Ethanol.—Many attempts have been made to deposit the metals of the rare earth family from solutions of their salts in various non-aqueous solvents, but have not met with any success. The preparation of the rare earth metals presents a problem of extraordinary scientific interest, in view of the fact that only six of the sixteen elements of this group have ever been obtained in the free form (Yt, Ce, La, Nd, Sm, Eu) and only two in a high state of purity (Ce, La).

Amalgams of many active metals have been prepared by the electrolysis of concentrated aqueous salt solutions using a mercury cathode. In several instances it has been found that amalgams of higher concentration can be prepared very much more readily and with less attendant decomposition by the use of non-aqueous ionizing media. Thus, Hevesy[1] prepared a 30 per cent barium amalgam by the electrolysis of a concentrated solution of the iodide in pyridine using a mercury cathode. Laszynski[2] prepared concentrated amalgams of potassium and sodium by electrolysis of the corresponding thiocyanates in acetone under similar conditions. Kettenbeil[3] also studied the preparation of amalgams of various elements, but was not able to prepare those "of the rare earth metals by electrolysis of their salt solutions at a mercury cathode." He reported negative results in his attempts to prepare amalgams of Ce, Yt, Di, Zr, and Th electrolytically using water, pyridine and alcohol as solvents.

However, amalgams of Yt, Ce, and La have been prepared by thermal methods and their properties studied. The decomposition of cerium amalgam has been suggested as a method for the purification of the metal.[4] In view of these facts it was decided to study the elec-

[1] Z. Elektrochem, vol. 16, p. 672, 1910.
[2] Ibid., vol. 4, p. 292, 1897.
[3] Z. anorg. Chem., vol. 38, p. 213, 1904.
[4] Hirsch. Trans. Am. Electrochem. Soc., vol. 29, p. 57, 1911; Ind. Eng. Chem., vol. 3, p. 880, 1911.

trolytic preparation of the amalgams of lanthanum and neodymium, a problem which was only recently brought to a successful conclusion[5] at the Chemical Laboratory of the University of Illinois.

Electrolysis of anhydrous neodymium chloride and of the monohydrated bromide in absolute ethanol, using a 110 direct current and with a current density of 0.06 to 0.15 amperes per square centimeter at a mercury cathode, results in the formation of pasty amalgams containing from 2 to 3 per cent of the metal. Such amalgams are quite reactive towards air, water, and alcohol and are best preserved in a vacuum or under a saturated solution of the electrolyte. Lanthanum amalgams are obtainable in a similar manner. Much of the mercury in these amalgams may be removed by distillation in vacuo, but not completely even at the temperature at which pyrex begins to melt. The products so obtained are extremely pyrophoric, black powders which take fire in air. By heating to a still higher temperature in specially constructed furnaces the free metals can be obtained.

The electrolytic preparation of these rare earth metal amalgams from non-aqueous solutions thus offers a method for obtaining at least these two metals in a high state of purity.

Metathetical Reactions in Non-Aqueous Solvents.—It is well-known that ordinary ionic reactions can be carried out in solvents other than water. These are particularly useful where hydrates are to be avoided, or where the preparation of compounds, not capable of existence in aqueous solutions, is involved. Several typical reactions are presented below.

Third-group cyanides and thiocyanates are immediately hydrolyzed by water, but are stable in liquid ammonia solution. If it is desired to prepare aluminum or rare earth metal cyanides, the interaction of the free metal with mercuric cyanide in liquid ammonia affords a very convenient method:

$$3\ Hg(CN)_2 + 2\ Me''' = 2\ Me(CN)_3 + 3\ Hg$$

Thus, "misch-metal" displaces mercury from mercuric cyanide in liquid ammonia to give a mixture of the rare earth metal cyanides. This reaction is best carried out in a closed tube at room temperatures.

It is difficult to prepare anhydrous rare earth metal iodides, and here again use can be made of several non-aqueous solvents, acetone or pyridine, and a reaction similar to the one above. Thus, a mixture of rare earth metal iodides can be obtained by the interaction of misch-metal and mercuric iodide in either pyridine or acetone solution.

$$3\ HgI_2 + 2\ Me''' = 2\ MeI_3 + 3\ Hg$$

[5] Audrieth, Jukkola, Meints, and Hopkins, J. Am. Chem. Soc., vol. 53, 1931.

An interesting series of reactions has been carried out involving the direct interaction of halogens with misch-metal in various solvents. Free bromine and misch-metal shavings were allowed to react together in ether, in carbon tetrachloride, carbon disulfide and in ethyl bromide. Only in ether was an appreciable reaction noticeable, after shaking for 24 hours, with separation of copious quantities of a yellow solid. This product was found to be very soluble in acetone, in absolute alcohol, and in pyridine. As the misch-metal employed was composed largely of cerium, it was shown that the metal had been oxidized to the ceric state and that the yellow solid consisted mainly of ceric bromide.

Interesting directional experiments carried out recently indicate that mercury diethyl and misch-metal react, presumably with formation of the rare earth metal alkyls. Lead tetraethyl and anhydrous neodymium chloride also react in ether solution with formation of triethyl lead chloride and the mono-ethyl neodymium dichloride.

Conclusion

As has been shown briefly in this paper, non-aqueous solvents find application in a variety of metathetical and electrolytic reactions. It is suggested that many solvents are available for carrying out reactions similar to those described above, where the presence of water would be decidedly detrimental.

RECENT DEVELOPMENTS IN THE APPLICATION OF X-RAYS TO CHEMISTRY AND INDUSTRY

BY

CHARLES W. STILLWELL

University of Illinois, Urbana.

The possibility of determining the ultimate structure of crystals and other solid materials by recording their effect on X-rays was first realized by von Laue in 1913. It had long been known that an optical grating, consisting of many parallel lines ruled on a plane surface, would diffract visible light if the distance between the lines was of the same order as the wave length of the light. Von Laue had calculated that, if a crystalline substance were assumed to be built up of atoms regularly arranged in space, the distance between the planes of atoms in such crystals should be about of the order of the wave length of X-rays—one ten-thousandth that of visible light. Under these conditions crystals ought to diffract X-rays. Von Laue showed that they do, and out of his experiment has grown a new and productive branch of chemistry.

For many years after von Laue's experiment the only chemical application of this new tool was in the determination of the crystal structure of chemical elements and compounds of all sorts. A vast amount of crystal structure data accumulated but attempts to find some general principles which are followed by nature in building crystals of various sorts were, in the main, disappointing. Within the last two years the key to the situation has apparently been found through the efforts of V. M. Goldschmidt, Linus Pauling, and others, and we are now able to state the first law of crystal chemistry. "The structure of a crystal is determined by the ratio of numbers, the ratio of sizes, and the properties of polarization of its building stones. As the building stones of crystals we visualize atoms (or ions) or groups of atoms."[1]

It is important to note that atomic weight does not influence the type of structure which a crystal will assume, neither do chemical properties. A crystal does not weigh its building stones nor does it know any chemistry. It merely arranges them with regard to their number and their demand of space. Our conceptions of polymorphism,

[1] V. M. Goldschmidt, Trans. Faraday Soc., p. 253, 1929.

isomorphism, and similar phenomena have been greatly clarified by this law. Before the advent of X-ray crystal analysis we knew nothing about the fundamental nature of solids and if X-ray analysis had produced no other results than this it would have justified itself.

About six or seven years ago, however, it was realized that X-ray analysis could also be used to advantage in the examination and control of many industrial raw materials and products. To enumerate the materials which have been studied would be to name almost every type of product in existence. It is more satisfactory to mention the general classes of materials and the kinds of information which may be obtained in such investigations.

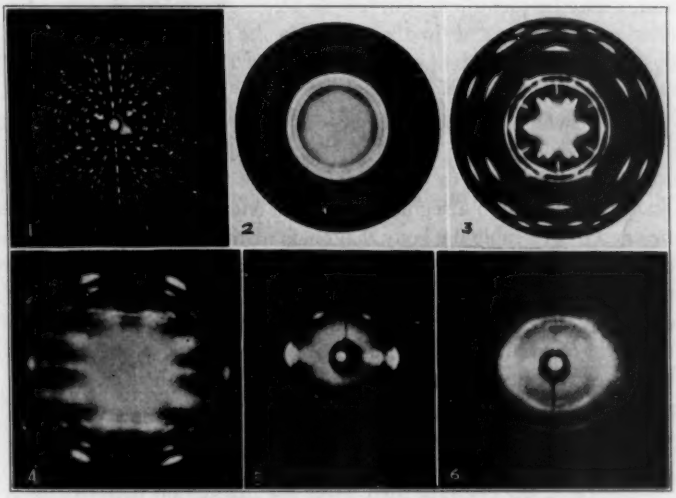


Fig. 1. Diffraction pattern of a single crystal of carborundum.
Fig. 2. Diffraction pattern produced by a large number of very small crystals in random arrangement.
Fig. 3. A typical fiber pattern showing preferred orientation of crystal grains along one axis. (Cold drawn aluminum wire.)
Fig. 4. Diffraction pattern for asbestos—an almost perfect mineral fiber.
Fig. 5. Diffraction pattern for ramie—the most perfect natural cellulose fiber.
Fig. 6. Diffraction pattern for rayon manufactured by an improved process. The high degree of fibering indicates high tensile strength.

If an X-ray beam is passed through a single crystal, a symmetrical pattern of spots is obtained (fig. 1). If the beam passes through a large number of very small crystals, the diffraction produces concentric rings on the photographic plate placed behind the specimen (fig. 2).

No two solids have exactly the same crystal structure, and no two give the same diffraction pattern. X-ray analysis, therefore, is very

helpful in identifying crystalline substances, in detecting and identifying impurities, in detecting changes which may occur during industrial chemical processes to produce new compounds, changes which in many cases would be very difficult to detect by chemical means. Perhaps the most successful of all applications of X-ray analysis has been in the study of alloys. When two metals are fused together they may form intermetallic compounds; they may dissolve in each other forming solid solutions, or they may merely be mixed in a superficial manner. The properties of the resulting alloy are greatly affected by the sort of combination which occurs and the X-rays are able to distinguish between these three types. Alloys in galvanized iron and other metallic coatings may be identified. Studies on electrodeposited films are being carried on at the present time, particularly the study of electrodeposited alloys. The X-ray method of analysis is ideal for such problems, and there are many of them.

A field which has been developed with much enthusiasm during the past three or four years is the examination of so-called fibered matter, either natural or artificial. This is material in which the crystals are oriented in a regular manner in one direction. For example, if the crystals are cubic the body diagonals of the cube may all be in one direction which is designated as the fiber axis. This condition is intermediate between that existing in a single crystal and that existing in a large number of very minute crystals. If a beam of X-rays is passed through the crystals perpendicular to the fiber axis, along which the crystals are oriented, then the crystals will affect them exactly as a single crystal would and spots, rather than concentric circles, will appear on the pattern. The more perfect the orientation of the crystal grains, the sharper will be the spots. One is able to estimate the degree of orientation of the crystals, then, from the diffraction pattern (fig. 3).

It has been learned that very important physical properties are influenced by this fundamental arrangement of the individual crystals. Tensile strength is probably the most seriously affected, and it increases as the orientation of the crystals becomes more perfect. The value of this discovery has been far-reaching. It applies to such materials as wire (which is a typical fiber produced artificially), cellulose, wool, rayon and other artificial silks, rubber, muscle fibers, surgical cat-gut, asbestos (a perfect mineral fiber), and many others. Almost everything in the vegetable and animal world which can be classified as a fiber under the common meaning of that term, shows this fiber structure, characteristic of crystals regularly arranged in one direction. It seems to be a general law of nature for things to grow in this orderly manner. Of course the orientation does not exist to the same degree

in all cases, as may be seen by an inspection of figures 4, 5, and 6. In many of these fibrous materials more perfect orientation may be induced by suitable chemical or physical treatment and the value of the material for certain uses improved thereby. To mention only one example, the process for spinning rayon has been almost completely changed as a result of information gained from X-ray diffraction patterns and the wearing quality of the product has been greatly improved.

Efforts are being made at the present time to design more powerful X-ray tubes so that the length of time required to obtain a diffraction pattern may be decreased. Remarkable progress has already been made, and there are tubes available that in from five to thirty minutes will take pictures which formerly required from four to forty-eight hours. Under very favorable conditions satisfactory pictures may be obtained in considerably less than five minutes. The possibility of instantaneous exposures opens up entirely new fields of investigation, especially the possibility of following chemical reactions in which structural changes occur. In many of the well established fields of X-ray research, however, time is not the important element.

Every conceivable type of substance has been examined by X-ray analysis. Much of this endeavor has produced definite and valuable results whereas some has been disappointing. In general, the more definitely crystalline a substance, the more complete will be the structural information obtainable. The development of crystal chemistry is just beginning and promises much. The structure of alloys may be deduced with great certainty and only a few of the several thousand possible alloys have been studied. The study of inorganic binary and ternary systems and the problems of mixed crystals, double salts, etc., offer a promising field for research. As one departs from purely crystalline substances one treads on less secure ground, and the less crystalline a substance is the less may be learned about its structure. The structure of cellulose has been rather definitely established; much is known of the structure of rubber and other fibers which are not as perfectly oriented as the best of cellulose fibers. The study of the X-ray diffraction of liquids, which of course are commonly classed as non-crystalline, is being persistently followed but so far has yielded very little conclusive information.

It is becoming evident that this new method of X-ray analysis has its limitations. It will be of little help in some types of problems, but this is in no way discouraging. It was necessary to attempt the analysis of all sorts of materials in order to reach the present stage of development, and it remains now to study more critically the fields in which X-ray analysis may be applied to advantage. A realization of the limitations of any tool enables one to use it more effectively.

A COMPARISON OF SCIENCE CURRICULA IN EUROPEAN AND AMERICAN SCHOOLS

BY

P. R. NEUREITER

Western Illinois State Teachers College, Macomb

The following attempt to parallel science education in America and Europe is made by one who has lived in Europe for twenty-eight years, who is entirely a product of European education and has been an instructor in an American college for the last three years.

In order to familiarize ourselves with the rough outlines of the European school system we shall pursue a French and a German boy on their educational careers from the first grade up to the happy point when they will be able to present themselves for the doctor's degree in one of the sciences. The picture thus obtained will hold good for a large number of countries as there is a striking resemblance between the educational systems in force on the continent. The schools of Great Britain, however, having their own distinctive traits, have been left out of this discussion.

A French child enters the grades at six, continues in them until the age of eleven when he or rather his parents and teachers have to make an important decision. Shall he go on to the higher elementary school from which he will graduate at thirteen in order to take up a wage-earning job or to continue in a vocational school, or shall he become a member of the select minority who are given a thorough training in the "lycées" or "collèges," the secondary schools of the country?

The child whose career we are pursuing will do well to transfer to the secondary school at this point. For this is the school from which he should graduate in order to enter the university, and obtain the doctor's degree. Should he fail to enroll in the secondary school at this time he would not necessarily be barred from access to higher education, but he would find it increasingly difficult to make the transfer at a higher age. It is a significant fact, however, that only about one-tenth of the pupils enrolled in the lower elementary schools go through the secondary schools, while about nine-tenths limit their education to the opportunities offered by the other branch of the system. (Fig. 1.)

The French secondary school extends over seven years between the ages of eleven and eighteen, and offers a choice of two curricula in the lower four-year cycle, and of three curricula in the two-year cycle. The seventh year offers an option between the "Classe de Philosophie," and "Classe de Mathématique," laying emphasis respectively on the literary studies, and mathematics and the sciences. Once a certain curriculum is chosen by the student, a definite set of sub-

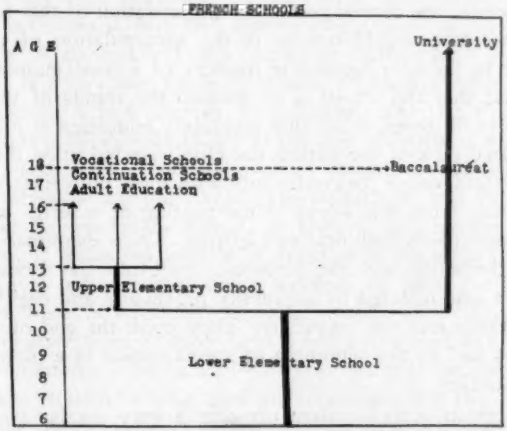


FIG. 1. Diagram illustrating the French school system.

jects is prescribed; the number of electives is negligible. It has been said that the European student has to get his education "Table d'hôte" whereas the American youngster has the privilege of studying à la carte. If the number of weekly recitations continued throughout the year is totaled in each subject for the entire seven years, the time allotment for every subject calculated on the basis of an average curriculum, is as follows:[1]

Subjects	Number of Recitations	Per cent of total curriculum
French	29	19.3
Foreign Language	51	34
History	16½	11
Geography	5	3.3
Mathematics	25½	17
Sciences	20	13.3
Philosophy	3	2
Total hours per week	150	100

[1] For further details see I. L. Kandel, "The Reform of Secondary Education in France," 1923, and "Educational Yearbooks," 1924—, published by International Institute of Teachers College, Columbia University.

As the efficiency of a school cannot be measured by the mere number of weekly recitations, the teaching process, too, deserves consideration. The French have been traditionally proud of their secondary school, and have striven to maintain the quality of instruction on a very high level. The instructors are selected by a competitive examination after having completed several years' work in the university. The curricula are frequently revised and overhauled by action of the government on recommendation of the Ministry of Public Instruction. Three principles are carried out in the organization of this school, first that the incentive should not lie in the accumulation of points and credits, but in the ever increasing mastery of a small number of subjects, second that the school is to develop the minds of the student, rather than to fill them, third, that secondary education is intended for the intellectual pick of the nation, the élite, selected upon the merit of a superior intelligence.[2] In conformity with these objectives a requisite for graduation from this school is the passing of a series of comprehensive examinations both oral and written. These examinations which include mathematics and the sciences, constitute the French baccalaureate, are administered by university professors and entitle the student to entrance into the university. They mark the end of secondary education as well as the beginning of specialization in a major field of the higher studies.

The German school system presents a very similar picture. All pupils stay in the grades between the ages of six and ten, when they arrive at the crossing of the roads. In Prussia about 88 per cent continue in the upper grades later to enter trade, vocational, and compulsory continuation schools, about 12 per cent are regarded by the parents and teachers as the intellectual "gentry," and venture into the secondary schools where they are put through a most rigid training characterized by uncompromising Teutonic thoroughness. To cater to the diversity of interests this field of secondary education is covered by not less than ten different types of schools each one having a definitely prescribed curriculum. The majority of these schools extend over nine years between the ages of ten and nineteen, and give prolonged concentrated training in a limited number of subjects. The place of science in the curricula of these schools is illustrated in Table I. Out of a total of two hundred fifty-three hours representing the sum of all the weekly recitations, continued throughout the year, for the entire course of nine years, mathematics receive between eighteen and thirty-five hours, or from 13 to 16.9 per cent of the total curriculum, sciences comprising biology, physics, and chemistry, receive from 7.1

[2] Quoted in part from an address by M. Paul Appell, Rector of the Sorbonne.

to 13.8 per cent, the actual number depending on the type of secondary school.

The German boy or girl may graduate from this school at the age of nineteen on passing the "Examination of Maturity" which, as in France, entitles him to enter the university, and being controlled by the universities, carries with it the admission to the institutions of higher learning.

Let me briefly outline the study of chemistry at a German university. At the very beginning of his work, the student selects his major and combines it with two minors which must be closely related to his major. A chemist will take courses in mathematics, physics, and mineralogy, but no other subjects outside of chemistry. (Some universities require a few courses in philosophy for the Ph. D.) His liberal education is officially closed at the age of nineteen with graduation from a secondary school. University education finds its sole purpose in professional training. While the young man was under a strict discipline in the secondary school, he enjoys, and frequently suffers from an almost unlimited amount of freedom in the university. There are no credits, honor points, quizz sections, or tests, but lectures at which attendance is voluntary, laboratory work of a definite content without a definite time schedule, and a few comprehensive and cumulative examinations. The rate of progress depends on the individual ability of the student. On an average, I estimate that the student will have finished his preparation in organic and inorganic, analytical, and physical chemistry at the beginning of the fourth year, and then will concentrate on the field in which he intends to work out his thesis. It will take him about three semesters to complete the dissertation so that during the tenth semester or the latter part of the fifth year, frequently at an age of twenty-four, he may obtain the Ph. D. provided that his thesis was approved and he passed a final examination in the major and minor subjects.

What does the comparison between the American and continental school systems demonstrate?

Owing to the fierce competition of European life and the exigency of stringent economy the aspirant to the highest degree in science is compelled to specialize early, he commences his scientific preparation at an age when the American youth has no reason to think or worry about his future. Consequently the European can, if he pairs industry and ability, reach the highest professional degree at an earlier age than does the average American. At nineteen the German boy has at least a reading knowledge of two foreign languages, he has been through a continuous, methodical course of training in mathematics,

including algebra, plane and solid geometry, trigonometry, analytics, and the elements of calculus; he knows the fundamentals of physics and chemistry. This intensive training is attainable only through the segregation of the pupils on the secondary level. There is no counterpart of the American high school on the continent. Over against one high school which in America educates the vast majority of the population, and consequently is burdened by a multiplicity of aims and objectives, Europe sets a differentiated system of secondary education with a variety of diverse schools each one of which aims at a well-defined purpose, serves a specific end. The great majority of the people do not expect to obtain any professional training in the university, therefore, they stay away from those secondary schools which prepare their pupils for university entrance by a difficult condensed course of training.

TABLE I.

TABULATION OF THE TIME SCHEDULES OF SIX TYPES OF GERMAN SECONDARY SCHOOLS.

	A	B	C	D	E	F	Total in per cent Min.	Max.
Religion	18	18	18	18	18	18	7.1	7.1
German	37	35	31	35	37	44	12.2	17.3
Latin	40	53	41	16	..	..	00.0	20.9
Greek	32	36	..	..	..	..	00.0	14.2
1st Mod. Language	32	15	20	44	40	46	5.9	18.1
2nd Mod. Language	..	..	27	23	22	13	00.0	10.6
History	17	19	20	22	22	25	6.7	9.8
Geography	12	12	13	13	14	18	4.7	7.1
Mathematics	33	33	36	37	43	37	13	16.9
Sciences	18	18	25	23	35	30	7.1	13.8
Drawing	10	10	18	18	18	18	3.9	7.1
Music	4	4	4	4	4	4	1.5	1.5
Total	253	253	253	253	253	253		

Letters signify types of schools:
A Reform-Gymnasium
B Gymnasium
C Real Gymnasium
D Reform-Real-Gymnasium
E Ober-Real-Schule
F Deutsche Oberschule

The European continent has nothing to place side by side with the American college. The unique experience of college life with its subtle values, so eminently educative for the future citizen, is not duplicated in the continental university. There the student is prematurely forced into the narrow path of specialization; except in his seminar work he lacks guidance, lacks encouragement, and those beneficial influences which tend to mold him into a good citizen.

* Compiled from the official decrees of the Prussian Ministry of Public Instruction. For further details see I. L. Kandel and Alexander, "The Reorganization of Education in Prussia," 1927.

Should I be permitted to express my very personal opinion on the comparative merits of the two systems, I should say that they must necessarily be different since they have to be adapted to different economic and sociological conditions; that the American Liberal Arts College is superior to anything that continental education has to offer; lastly, that the American public high school could do a still greater service to the nation if it gave more attention to the needs of the exceptionally gifted students of the intellectual cream of the nation from whose ranks will be recruited the scientific workers of America.

THE MODE OF OXIDATION OF ORGANIC ACIDS

BY

J. H. REEDY

University of Illinois, Urbana.

It is generally known that certain organic acids are readily oxidized, whereas others are decidedly resistant to wet oxidation. This paper is a report of a study made on the relation of oxidizability to the structure and electronic stability of the acid radicals involved. Credit is due Mr. C. S. Moyer and Mr. P. C. Yang, who carried out the experimental side of the investigation.

To the practical chemist, differences in the oxidizability of organic acids are "mere facts," and the mechanism of the reactions concern him very little. The theoretical chemist, on the other hand, regards these differences as highly important, for he uses them in building up his methods of separations and synthesis. The mechanism of the oxidation of organic acids is discussed mainly in terms of formic and oxalic acids. Both of these are recognized as active reducing agents, and yet there are marked differences in the modes of their oxidation. Some of these differences are shown in the following table:

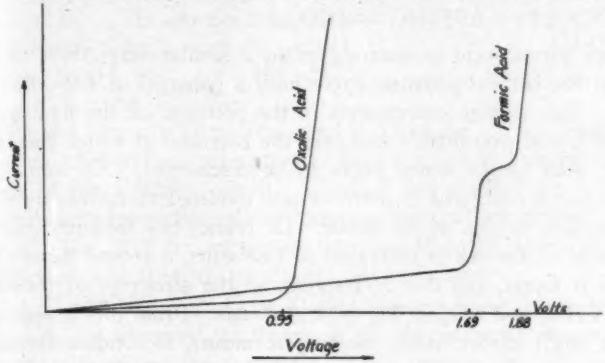
TABLE I.

REACTIONS OF FORMIC AND OXALIC ACIDS

Oxidizing Agent	Reaction with $HCHO_2$	Reaction with $H_2C_2O_4$
O_2 or O_3	H_2CO_3	———
Na_2O_2	$Na_2CO_3+H_2O$	$Na_2C_2O_4+H_2O_2$
HNO_3	H_2CO_3	———
MnO_2	$Mn(CHO_2)_4$	$Mn^{++}+H_2CO_3$
$HMnO_4$	Slow oxidation	Rapid oxidation (if Mn^{++} is present)
Fehling's solution	Cu_2O	———

Such differences can be explained only in terms of some fundamental differences in the mechanism of the oxidation processes. It appears that formic acid can be directly oxidized by all oxygenating agents, that is, agents that decompose, liberating nascent oxygen. Oxalic acid is unaffected by these agents except in the presence of a suitable catalyst. On the other hand, as is shown later, oxalic acid is oxidized only by linking the oxalate anion to a cation of changeable valence, forming an unstable salt.

The explanation of these differences is found in the electrolytic behavior of formic and oxalic acids. If molar oxalic acid is electrolyzed between electrodes of bright platinum under an increasing potential (fig. 1), there is at first only a slight current with no visible evidence of decomposition. Upon reaching a potential of 0.95 volt, there is



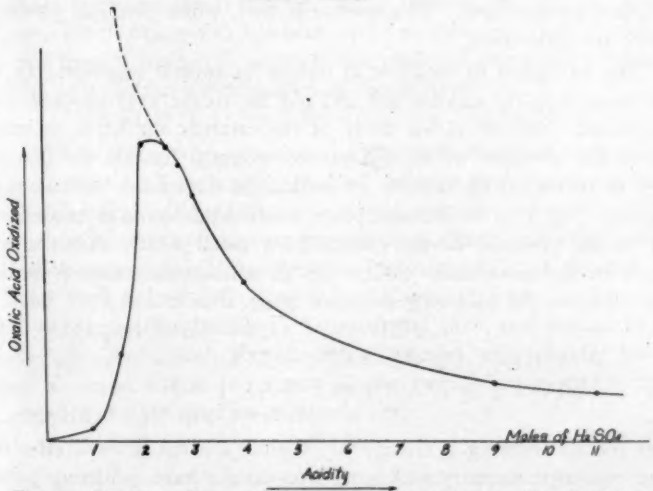


FIG. 1. *(Above)* **Decomposition potential curves for formic and oxalic acids.**

FIG. 2. *(Below)* **Curve showing effect of acidity upon the oxidation of oxalic acid by nitric acid, using Mn as a catalyst.**

a rather abrupt increase in current, and carbon dioxide begins to be liberated at the anode. This critical potential of 0.95 volt is called the "decomposition potential" for oxalic acid. This potential is almost exactly the same as the decomposition potential of hydrobromic acid.

This would call for the displacement of the oxalate group by chlorine, just as the bromine ion is displaced, and this is exactly the case:

$$2\ Br^- + Cl_2 \rightarrow Br_2 + 2\ Cl^-;$$
$$C_2O_4^{--} + Cl_2 \rightarrow 2\ CO_2 + 2\ Cl^-.$$

The reaction involved is simply the discharge of the oxalate anion:

$$C_2O_4^{--}(+\ 0.95\ \text{volt}) \rightarrow 2\ CO_2 + 2\ \text{elctrons}.$$

When formic acid is electrolyzed in a similar way, there is no flexure in the current-potential curve until a potential of 1.69 volts is reached. This voltage corresponds to the potential of the hydrogen-oxygen cell, and presumably indicates the potential at which the H^+ and OH^- ions of the water begin to be discharged. As would be expected, the formic acid is more or less oxidized to carbon dioxide by the nascent oxygen at the anode. Le Blanc[1] has reported that if the potential of the cell is increased to 1.88 volts, a second flexure in the curve is found, and this corresponds to the discharge of formate ions: $2\ CHO_2^- \rightarrow 2\ CO_2 + H_2 + 2$ electrons. From this it appears that it is much harder, using electrolytic means, to oxidize formate ions than oxalate ions. The reverse is true, when chemical oxidizing agents are concerned.

The oxidation of oxalates is unique in several respects. In the first place, it is the oxalate ion and not the oxalic acid molecule that is oxidized. Sellers[2] in his study of the catalytic oxidation of oxalic acid in the presence of manganous compounds, has shown that the speed of oxidation of oxalates by nitric acid diminishes with increase in acidity (fig. 2). In the next place, oxalic acid seems to be oxidized only in the presence of the cations of a metal which shows a well defined change in valence. Sellers has shown that the reaction may be represented by the following sequence of equations:

$$Mn^{++} + 2\ OH^- + C_2O_4^{--} \rightarrow Mn(OH)_2\ C_2O_4;$$
$$Mn(OH)_2\ C_2O_4 \rightarrow Mn(OH)_2 + 2\ CO_2;$$
$$Mn(OH)_2 + NO_2\ (\text{from}\ HNO_3) + 4\ H^+ \rightarrow Mn^{++++} + NO + 3H_2O.$$

Other metals showing a change of valence are not always effective. Silver, mercuric mercury and ferric iron do not have oxidizing potentials high enough, and tetravalent lead in the form of lead dioxide is too insoluble in weak acid solution to form an oxalate. Next to manganese, vanadium seems to be the most suitable catalyst.

The oxidation of formates is in every respect similar and parallel to the oxidation of aldehydes. (See Table II.) Since both contain the CHO-group, the mechanism is clearly characteristic of this radical.

[1] Zeit. phys. Chem., vol. 8, p. 299, 1891.
[2] Thesis, University of Illinois, 1929.

TABLE II

REACTIONS OF FORMIC ACID AND ALDEHYDES WITH OXIDIZING AGENTS

Oxidizing Agent	Reaction with HCOOH	Reaction with CH_3CHO
O_2	H_2CO_3	CH_3COOH
$Ag(NH_3)_2OH$	Ag deposit	Ag deposit
Fehling's Soln.	Cu_2O	Cu_2O
HgO	$Hg+H_2CO_3$	$Hg+CH_3COOH$

Both the formic acid molecule and the formate ion are good reducing agents. Several mechanisms have been suggested to explain the oxidation of the aldehyde group. Wieland[3] has studied the oxidation of aldehydes very extensively and proposed several mechanisms to explain them. In 1912 he suggested the idea that the aldehyde was first hydrated, and then hydrogen split out as follows:

$$RCHO + H_2O \rightarrow RCH(OH)_2 \rightarrow RCOOH + H_2.$$

In 1921 he advanced the theory of the formation of peracids as intermediate in the oxidation process. More recently, in 1923, he proposed a peroxide theory, which has been very favorably received. According to this theory, oxygen is added to the carbonyl group, forming a peroxide, followed by the migration of the H atom:

$$2\ RCHO + O_2 \rightarrow 2\ RCH(O_2) \rightarrow 2\ RCOOH.$$

While other representatives of the more common organic acids have not yet been thoroughly studied, some general statements may be made in regard to their behavior. Acetic, succinic and similar acids are known to be very resistant to wet oxidation, being only slowly affected by such strong oxidizing agents as permanganic and chromic acids. Under such drastic oxidation, only the final products, carbon dioxide and water, can be identified. Tartaric and citric acid are fairly active reducing agents, with decomposition voltages only slightly less than that of water. This indicates that their oxidation is due to nascent oxygen, just as in the case of formic acid.

[3] Ber. 45, II, 2606-15 (1912); ibid. 54B, 2353-76 (1921); Ann. 431, 301-22 (1922).

CHEMICAL RESEARCH IN ICE MANUFACTURE

BY

D. B. KEYES

University of Illinois, Urbana.

In considering the industrial growth of the country during the past twenty years it is interesting to discover that one of the major industries which developed during this period was the production of artificial ice. It is only possible to gain an accurate conception of the true proportions of this development by considering the fact that during 1929, 54,000,000 tons of ice were produced, the retail value of which was approximately $400,000,000. As, in addition to its size, the industry is intimately connected with the efficient maintenance of public health, its problems deserve particular attention in the form of effective research. In the past this attention has been centered in studies concerned with the efficient operation of the mechanical units comprising the refrigerating cycle. During a recent investigation conducted at the University of Illinois, however, problems more intimately concerned in the production of artificial ice itself have been made the basis of extensive research.

From a mechanical standpoint the manufacturing process does not include an extremely involved procedure. A gaseous refrigerant, usually ammonia, is compressed to a liquid by means of mechanically operated compressors and is then allowed to boil at the expense of heat absorbed from a concentrated salt solution containing either sodium or calcium chloride, commonly called a brine, the freezing point of which is below that of pure water. Heat exchange is effected in an apparatus which effectively separates the two liquids by means of a metal wall. The ammonia vaporized during the process is again compressed, cooled in a water condenser, and returned as a liquid to the evaporator, thus operating as a continuous, closed system. The net effect of using the refrigerant is to remove heat from the brine and to deliver the heat thus extracted to the condenser water used to cool the ammonia gas following its compression.

The brine, cooled by the removal of heat in the ammonia evaporator, is rapidly circulated past steel cans containing the water to be

[1] This article is based on data previously published in Engineering Experiment Station Bulletin No. 219, "The Treatment of Water for Ice Manufacture," by Professor Dana Burke, Jr., Chemical Engineering Division, University of Illinois.

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frozen. Ice is formed at the sides and bottom of the cans thus leaving the unfrozen water confined in a core bounded by the growing walls of ice. When the water is completely frozen the cans are removed from the brine and placed in a thawing tank which is filled with warm water. Here a thin layer of ice is melted from the sides and bottom of the cans, thus allowing the ice to be removed. The ice removed, the cans are refilled with water and returned to the freezing tank.

The production of ice is thus seen to result from the expenditure of mechanical energy, the total work required being equivalent to that used by the compressors to return to its original liquid state the ammonia vaporized during the extraction of heat from the brine. In the original plants the only economical motive power available was that obtained from coal burned to produce steam, a procedure which fortunately served a double purpose, as the steam after being passed through the compressors was condensed to produce distilled water. When this water was quietly frozen in cans immersed in the freezing brine the ice produced was invariably transparent, due to the almost complete absence of dissolved salts. The effect of this practice was destined, however, to play an important rôle in the future economic development of the industry itself, for the consuming public finally arrived at the point where it demanded the transparency that it had been early educated to expect.

The full effect of this demand for transparent ice became apparent with the next major development affecting the industry. With general industrial growth it gradually became evident that power could be produced more economically in central power stations as electrical energy than in small individual steam installations. It was determined in the case of the ice industry, for example, that a ton of coal burned in a steam-driven ice-plant would produce from 4 to 6 tons of ice, whereas the same amount of fuel burned in a central power station would generate sufficient electrical energy to produce from 16 to 18 tons of ice when the plant was electrified. Electrification afforded savings in ice production cost of from $0.40 to $1.00 per ton.

In the electrified ice-plant, however, distilled water was no longer available for the ice and natural water supplies had to be used in its place. Such water always includes varying amounts of dissolved salts and when quietly frozen, according to the procedure giving transparent ice from distilled water, the product is completely opaque, as indicated in figure 1.

The reason for the production of opaque ice from solutions containing dissolved salts will be readily understood upon reviewing the conditions to which such solutions are subjected on being cooled. As

the temperature is lowered, a point is finally reached at which solid water or ice forms, and as heat continues to be absorbed from the solution, the formation of ice continues. With the separation of water as ice, however, the salts in the unfrozen solution are more and more concentrated, until a point is finally reached at which either of two conditions occasioning the formation of opaque ice results.

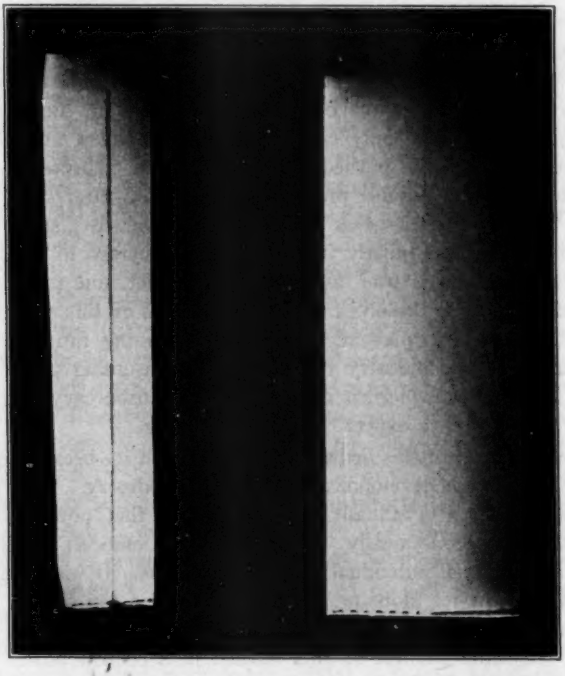


Fig. 1. Ice frozen from a solution containing dissolved salts under conditions that invariably produce highly transparent ice when the solution being frozen is distilled water and therefore free from salts. This ice is completely opaque, opacity having resulted from the fact that its optical properties have been materially affected by the presence of the dissolved salts in the water from which the ice crystals formed.
(Courtesy Engineering Experiment Station, University of Illinois.)

If the composition of the original solution is such that an insoluble compound may be formed as the result of concentration, solid salt will eventually separate with the ice as an eutectic mixture. Due to the fact that an eutectic generally possesses optical properties which differ from those of pure ice alone, the solid will appear opaque. A further disadvantage of the separation of an eutectic mixture lies in the fact

that when the ice melts the salt does not redissolve but remains behind as an insoluble sludge which either clogs up the drain in the domestic ice-box or coats the produce which it is used to cool during shipment to market. The separation of salt with the ice may be prevented, however, by treating the water chemically before it is frozen so that the salts of low solubility are converted into more soluble compounds. This may be effected, for example, by neutralizing the carbonates of calcium and magnesium to the corresponding sulphates, a process commonly accomplished by means of aluminum sulphate.

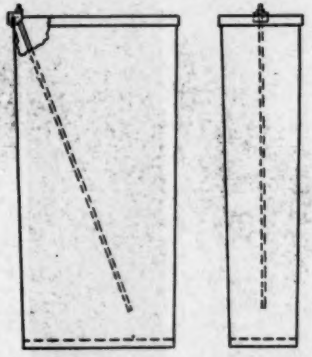


FIG. 2. A typical method of applying air to obtain agitation of the solutions being frozen according to procedure which has become standardized in the ice industry. The air enters the solution at a single point, and maximum agitation results in the center of the solution. When the initial salt concentration and the rate of crystallization are high such agitation is ineffective in preventing the formation of opaque ice at the freezing surface where the dissolved salt has a tendency to concentrate locally.

The second condition occasioning the formation of opaque ice results when the dissolved salts become sufficiently concentrated to affect the physical characteristics of the individual ice crystals themselves. The environment in which a crystal forms exerts a decided effect on both its habit and orientation. When these properties become materially altered, light passing through the solid is sufficiently scattered to cause the mass to appear opaque. The general phenomenon is quite common. For example, a large transparent crystal on being pulverized is reduced to a mass which appears opaque, even though the individual crystal units themselves remain perfectly transparent.

To overcome the formation of opacity from this cause any localized salt concentration at the surface of the growing crystal must be prevented and the unfrozen solution must be removed whenever the salts become concentrated to the point where the orientation and habit of the ice crystals are affected. Removal of the unfrozen core water

obviously necessitates refilling the core cavity with a fresh supply of the water originally used.

When the salt solution is first subjected to freezing, extremely rapid cooling takes place at the sides of the metal can. This results from the fact that the heat conductivity of steel is comparatively high

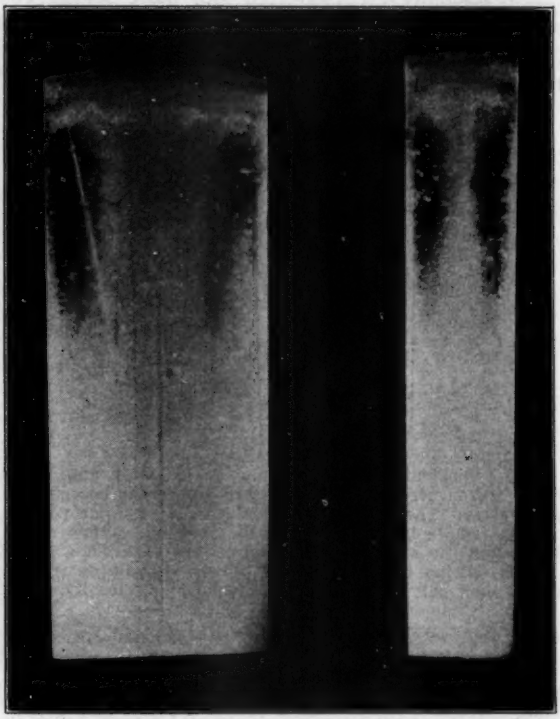


Fig. 3. Ice from a solution containing a high concentration of dissolved salt frozen under conditions resulting from air agitation applied according to the method illustrated in Figure 2. The opaque shell encasing the ice cake and the thick opaque core are typical results of ineffective agitation. Ice of this quality is thoroughly unmarketable. In the past the only remedy for this condition has been to distill the water to remove the salts. Such procedure prevents the electrification of the manufacturing process and materially increases the cost of production.
(Courtesy Engineering Experiment Station, University of Illinois.)

and that the freezing brine in the average plant is maintained at a temperature 16° F. below that at which ice initially forms.

This layer of ice which forms first is of course surrounded by all of the unfrozen solution. Actually, however, it may be considered to

be bounded by only a thin film of the salt solution. The conditions existing in this fluid film not only affect the physical characteristics of the crystal but also determine the physical characteristics of the final cake of ice. As growth of the ice surface depends upon its continued ability to remove water from this fluid film, there is a decided tendency for the salts present in the film to become locally concentrated, the extent of this tendency being dependent upon the initial concentration of the salts in the solution and the rate at which ice is formed at the crystal face. Unless local concentration of the salt is prevented, the

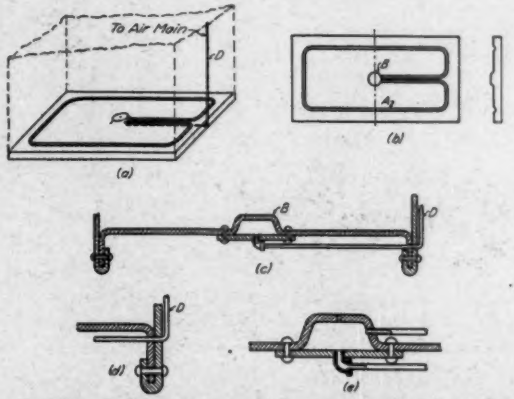


FIG. 4. **Details of the new type of ice-can developed at the University of Illinois. The air for agitation is forced to enter the solution through a series of small holes in a header located at the extreme sides of the can as indicated in *(a)*. The ice which initially forms while the rate of crystallization is high is thus effectively agitated. When the rate of crystallization is materially reduced by the formation of a sufficiently thick layer of ice through which heat must be removed by the brine, a much smaller amount of air applied from a point located centrally in the can as at B in *(b)* is sufficient to prevent the formation of opaque ice. When the air supply is reduced, ice forming in from the sides of the can effectively plugs the holes in the outer header and allows the final air to enter only from the hole at B. Details of the can's construction are indicated in *(c)*, *(d)* and *(e)*.**

critical concentration affecting crystal orientation may be reached in the film long before the concentration of the salts in the main body of the unfrozen solution is materially altered.

The best way to prevent local concentration in the surface film is to agitate the solution as it is being frozen, thus mixing the concentrated salt solution formed in the fluid film with the main body of the solution which is more dilute. In common practice agitation is accomplished by expanding air under pressure into the bottom of the cans of water. The air in rising to the surface imparts a certain motion to the liquid which in turn results in the desired mixing. In the past, however,

the agitation developed by means of air has been relatively inefficient. The air was delivered to a single point located near the center of the bottom of the can (fig. 2) resulting in the effective movement of the liquid being limited to the form of an inverted cone whose apex corresponds to the point of entry of the air. The maximum agitation results, not at the sides of the can, but in the center. It is at the sides,

Fig. 5. Ice from the same water which produced the unmarketable product shown in Figure 3 frozen in the new type of ice can shown in Figure 4. In order to judge the quality of this ice from the standpoint of transparency, reference should be made to Figure 6, which indicates the ice produced from distilled water agitated by air during the freezing operation.
(Courtesy Engineering Experiment Station, University of Illinois.)

however, that the most effective agitation is needed, especially during the initial freezing. An example of inefficient agitation where the initial salt concentration of the water being frozen is high is shown in figure 3. As a result of such procedure it has formerly been considered impossible to produce marketable ice from raw water sources containing salts in excess of six hundred to seven hundred parts per million.

During the course of the present investigation a new type of freezing can has been developed whereby the efficiency of the air agitation imparted to the solution is greatly increased. The construction of the new can is indicated in figure 4. The air is forced to enter at the extreme sides of the can, thus causing maximum agitation to

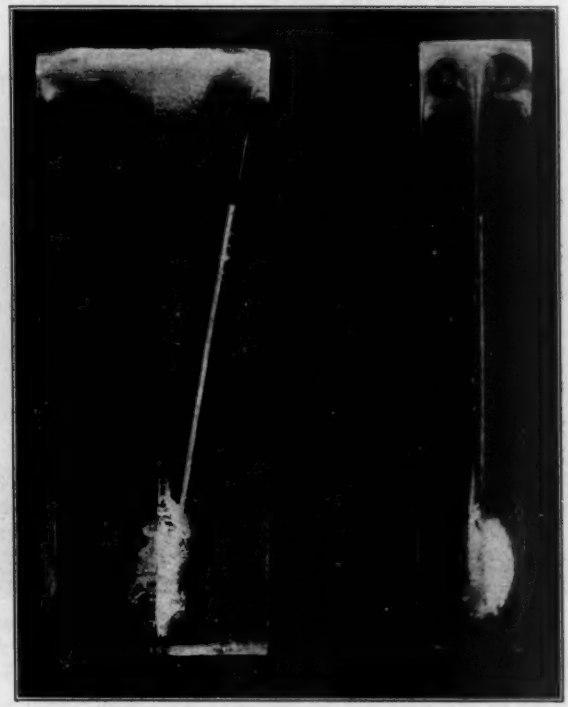


FIG. 6. Ice frozen from distilled water agitated by means of air throughout the freezing operation. Opacity in this case results from the fact that the final water which freezes is whipped into and freezes as an air foam, the optical properties of which differ sufficiently from those of ice alone to cause light passing through the ice cake to be materially scattered.
(Courtesy Engineering Experiment Station, University of Illinois.)

exist always at the surface of the ice. In figure 5 is shown the result of using the new can in freezing the water which produced, under standard freezing procedure, the thoroughly unmarketable product shown in figure 3. For comparison, ice frozen from distilled water is shown in figure 6.

As a result of this investigation it has been determined, on the basis of both laboratory and plant scale operations, that thoroughly marketable ice can be made from any natural water source which may be considered as an industrial supply, so that it is no longer necessary to distill water in order to render it suitable for the production of marketable ice. Approximately one-third of the ice produced is still being manufactured in steam plants in spite of the lower operating

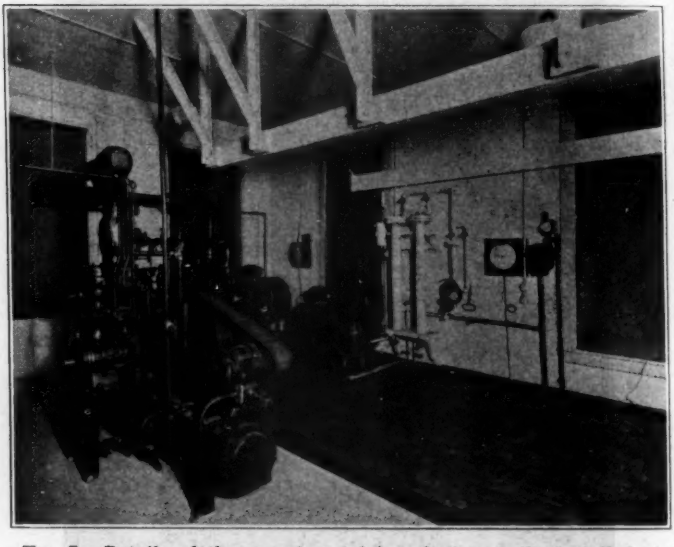


Fig. 7. Details of the experimental ice plant recently installed at the University of Illinois to facilitate further investigation of problems involved in the efficient manufacture of artificial ice.

cost which electrification offers. Undoubtedly factors other than the inability to produce marketable ice in electrified production exist in many steam installations. The steam generating equipment, for example, may have been so recently installed that the depreciation loss incurred by its removal cannot yet be economically absorbed. As the result of the present investigation, however, control of the physical and chemical conditions at the surface of the growing ice crystal has been shown to be sufficient to produce clear, transparent ice in electrified plants, whenever desired, from any natural water found in the United States.

INFLUENCE OF LOCAL INDUSTRIES ON THE DETERMINATION OF THE CHEMISTRY CURRICULUM

BY

WALDO HORRABIN

Western Illinois State Teachers College, Macomb

During the last ten years, and especially the last half of the decade, the matter of a desirable curriculum in high school chemistry has been thought upon by various chemistry teachers. They are quite correctly asking themselves if much of the material upon which they drill is in the curriculum for purely traditional reasons. They have wondered if there is not a body of subject matter right in the students' immediate neighborhood which is far more important to his use in understanding his own environment. What should then be the content of the high school chemistry course? Various groups interested in science education have attempted an answer to this question. The American Chemical Society Committee on Chemical Education has called to our attention a group of "Minimal Essentials" which in their opinion must be met in the curriculum. These points of subject matter are extremely well chosen and quite above question. In fact the average high school text goes far beyond them. Obviously there is a well chosen body of subject matter which we term as fundamentals which every acceptable course must contain. Every teacher will of course see that these fundamentals are mastered.

Now there is another distinct group of chemical facts which bear a direct relation to minimum essentials and which rank equally with them in importance. We have chosen for purposes of identification to designate them as "local essentials" of the curriculum. By local essentials we mean the things and materials which influence the every day life of the student, facts with which he rubs shoulders right in his own community. Facts which if well understood will aid him in making better use of his environment and aid him in his appreciation of local problems.

The cardinal objective of teaching high school chemistry (Committee on Education, American Chemical Society) is stated thus:

1. To show the service of chemistry to the home, to health, to medicine, to agriculture, to industry, etc.—In a word, to show the service of chemistry to the nation and to humanity.

You will notice that the primary aim is not to prepare students for special college work or make technicans. In other words it is to prepare them for life, to give them a better understanding of their immediate local surroundings.

Assuming this aim to be the correct one, then is it not true that a great many of us have failed to fulfill it if we have failed to teach the student in every available opportunity in terms of his local needs. How many of us have stressed some obscure application in the field of industry to the neglect of one more important to the student closer home?

At present the college and university are beginning to believe that they can teach fundamentals better than the high school. This is probably true. If it is true, then more than ever before comes to the high school the job of developing interest and appreciation for the subject so that it will be the field of the student's choice in the college and university.

With all these points in mind a group of us set out to determine for our own use the relation of chemistry to the lives of boys and girls in our own neighborhood. At first thought it did not seem such a difficult job but we were soon amazed to find how intricate and involved were the applications of chemistry. The moment we thought we were through, some new and overlooked point would arise. We visited industrial plants, stores, garages, photographic galleries, etc. In fact sixty-three different sorts of trades and businesses were visited. When we thought we had exhausted the list one of my practice teachers said, "We have visited every place except the banks, and there would be no need of going there." He was mistaken, for the important facts of tear-gas bombs and various inks were to be uncovered there. We are not so much interested today in the actual results as the use that was made of it. We had quite specific information about our local industries, and everyday facts of a chemical nature which should be called to the attention of the student; we then set to work making a curriculum embodying these local applications. Before the investigation we knew of the local applications in a very general way, now we knew them in a specific way. In order to make this material available it was first carefully organized. Our next step was to insert each fact of local importance brought out by our study into a text book which we were using. For example: Under the topic of chlorine was placed all the information we had gathered about chlorine in our inspection of the city water works. The material was definite and complete. No need for making estimates or guessing. Under the topic of lead

was inserted notes on the material supplied by the local battery station and plumber. In other words we knew that the material must be made usable or we would simply slip into the old rut. We recognized also that definite and accurate material is of more value than indefinite approximation and opinion. We found at once that this made our material extremely easy to handle and that we were able to introduce it at a time when it meant most to the students.

We feel that actual teaching results have repaid us for our trouble. We have noted the following results:

1. An awakening of interest which I do not think could have been secured in any other way.

2. When students found that we were stressing local applications they immediately began to supply them themselves. They became seekers of applications which is perhaps the most important result.

3. The development of a greater interest in less local and more general industrial applications and an appreciation for the service of the subject.

4. By means of this vitalizing of subject matter we found it increasingly easy to teach the fundamentals. In other words when they saw a reason for learning fundamentals they were perfectly willing to do so. In this way we made use of a very useful tool for motivation.

One other important viewpoint can be taken. It is often said that one trouble with our city and national government is that there are not enough officials and lawmakers trained in the elements of sense. Of course it can certainly be carried to our voters. Now for example, as a recent investigation shows, 28 per cent of our city ordinances over this country, such as smoke nuisance, sewage disposal, etc., require a science background. We can make vastly more intelligent voters on these topics. We can show for instance, that smoke nuisance is a dangerous, wasteful practice and quite easily remedied and perhaps give to these future citizens something which will help them solve their local problems of a science nature.

You will say, "Every good teacher has done this already." Perhaps that is true. We all think we do it but too many make the mistake of being far too general and indefinite. Unless we have really investigated we too often overlook more than we can well afford to pass by in view of the existing philosophy of chemistry teaching.

From the Ohio School Standards we find this statement: "We should like to express the hope that all teachers will get away from the notion that the studying of lessons by the pupils is like learning the lines of a play and that the recitation is the dress rehearsal. Nothing

seems more visciously unpedagogical than these parroted recitations that reveal no instructional ideals higher than the repetitions of subject matter."

It was in order to accomplish this that we set out to make our investigation and then establish a curriculum based thereon. We hope that if any of you have not been thinking along these lines, it may prove a suggestion.

DETERMINATION OF METHANOL IN THE PRESENCE OF ETHYL ALCOHOL

BY

F. S. MORTIMER

Illinois Wesleyan University, Bloomington

INTRODUCTION

Several methods have been proposed for the determination of methanol in the presence of ethyl alcohol and water. Practically all of these methods depend upon the oxidation of the methanol to formaldehyde and the subsequent determination of this substance.

Leach and Lythgoe (J. Amer. Chem. Soc., Vol. 27, p. 964, 1905), however, have proposed a method by which both methyl and ethyl alcohols may be found by a determination of two physical properties. These investigators have pointed out that equal weight concentrations of these two alcohols in water have nearly the same density; hence a determination of the density makes it possible to estimate the total alcoholic content of the mixture. In order to determine the relative amounts of each alcohol present, it was assumed that "addition of methyl to ethyl alcohol decreases the refraction in direct proportion to the amount added."

Leach and Lythgoe gave no data (except the analyses of some synthetic mixtures) for the refraction of ternary mixtures of water methanol, and ethyl alcohol. It was our purpose to determine this data and to attempt thereby to develop a graphical method for the analysis of methyl and ethyl alcohols in the presence of water or, for that matter in the presence of any non-volatile impurity.

It soon become apparent that the results, especially those for refractive index, are much more regular for mixtures containing less than 50 per cent of total alcohol by weight than for those which contain more than this amount. As all mixtures may readily be brought within this range of concentration, only this portion of the system has been investigated.

Procedure

The samples of alcohol used in this investigation were treated to remove impurities, but they were not rendered absolutely dry. The amount of water present was determined and allowance made for it in calculating the concentrations. Two stock solutions, each containing the two alcohols, were made up. Solution I contained 36.68 parts of methyl to 61.32 parts of ethyl and Solution II contained 73.97 parts of methyl to 26.03 parts of ethyl alcohol, the solutions being made up on the weight basis. Appropriate mixtures of each of these stock solutions were then made up with water in small glass-stoppered bottles and the refractivities determined at 20° C. by means of the Zeiss immersion refractometer using the standard procedure. Two other solutions, one containing 50 per cent by weight of methanol in water and the other 50 per cent by weight of ethanol in water were also prepared. As the densities of these two liquids are nearly the same, appropriate mixtures were made up on a volume basis and the refractivities read as before. The results for all mixtures are shown in Table I.

Table I

Refractivities of Ternary Mixtures of Methyl and Ethyl Alcohols With Water

Solution I		Solution II		Solutions III and IV		
Total % Alcohol	Scale reading	Total % Alcohol	Scale reading	Parts 50% Methanol	Parts 50% Ethanol	Scale Reading
0.0	14.5	0.0	14.5	100.	0.	39.8
		4.62	18.0	90.	10.	45.0
4.26	19.1	8.85	21.7	80.	20.	50.2
6.93	22.6	16.25	28.4	70.	30.	55.7
13.3	31.1	22.6	34.8	60.	40.	60.9
16.5	35.7	27.95	39.6	50.	50.	66.0
26.5	50.0	36.8	46.0	40.	60.	71.0
34.1	59.2			30.	70.	76.1
45.7	68.5			20.	80.	81.1
				10.	90.	86.0
				0.	100.	90.8

These results together with the results of Leach and Lythgoe for the pure alcohols, were plotted to a large scale and the concentrations for even refractometer scale readings were read off and used in plotting the ternary diagram shown in figure 1. It will be noted from this diagram that the lines of equal refraction, although nearly straight, are not quite parallel. Neither are they equally spaced. This last condition, at least, would have to obtain in order for the method of Leach and Lythgoe to give exact results in the analysis of samples containing methanol. However, with the density and refractivity determined, it

is not difficult to find from the ternary diagram the relative amounts of each of the three substances present in the mixture, provided, of course, that there are not more than traces of other volatile substances present to interfere.

We have found however, that a method of "factors" may be used by which it is possible to calculate very closely the percentages of methanol and ethanol present without the bother of constructing and interpolating from the ternary diagram.

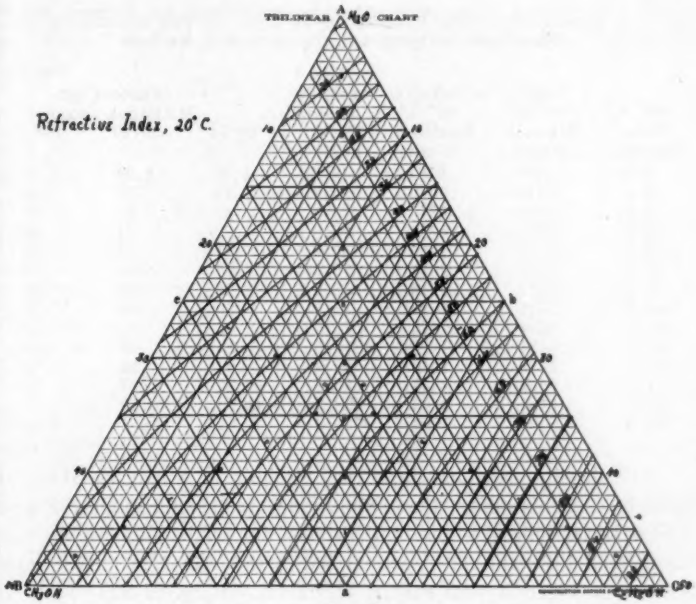


FIG. 1

Following are the steps in this method: (1) obtain the refractometer reading at 20° C. and the density at 20°/4°; (2) using the density tables for ethyl alcohol-water, find the weight per cent of total alcohol present in the solution; (3) with this per cent of alcohol find what would be the refractometer reading if ethanol were the only alcohol present; (4) subtract the actual refractometer reading found in (1); (5) multiply this difference by the appropriate factor and the product will represent the per cent of methanol present in the sample. The factor to be used is found in Table II after that number which represents the total per cent of alcohol in the sample as found from the density. The factor to be used first is that one in which it is

assumed that not over one-half of the total alcohol is methanol, viz. column 5. If after multiplying, it turns out that the ratio of methanol to ethanol is greater than 1 to 1 (this is seldom the case) then it is possible to make another estimate from the data of Table II and obtain a more appropriate factor. To facilitate its use, all of the data of Table II should be plotted on one graph, using per cent alcohol as one of the co-ordinates.

TABLE II

DENSITY, REFRACTIVITY AND FACTORS TO BE USED IN THE DETERMINATION OF METHANOL IN THE PRESENCE OF ETHYL ALCOHOL

Wt. % Total Alcohol	Density 20°/4° Ethanol-Water	Density 20°/4° Methanol-Water	Refractivity of Ethanol-Water at20°	Factors for Methanol/Ethanol 50/50	80/20	100/0
0.0	.9982	.9982	14.5	1.00	1.00	1.00
4.0	.9910	.9910	20.7	.87	.92	.96
8.0	.9847	.9845	27.8	.81	.87	.92
12.0	.9791	.9784	35.0	.80	.84	.88
16.0	.9739	.9726	42.5	.795	.82	.86
20.0	.9687	.9667	50.5	.79	.81	.83
24.0	.9632	.9610	58.2	.79	.80	.81
28.0	.9571	.9549	65.5	.80	.81	.81
32.0	.9504	.9485	71.7	.83	.84	.84
36.0	.9431	.9416	76.9	.88	.88	.88
40.0	.9352	.9345	81.3	.93	.93	.93
44.0	.9269	.9268	85.2	.98	.97	.97
48.0	.9183	.9183	88.7	1.00	.99	.99
52.0	.9099	.9099	91.8	1.01	1.00	1.00

The density data for these two alcohols in water are shown in Table II. The data for ethanol solutions are taken from the Bureau of Standards Bulletin 9, No. 3. The data for methanol solutions were interpolated from the data summarized in the Van Nostrand's Chemical Annual together with that of Hertz (Z. Anorg. Chem. 104, p. 47, 1918).

TABLE III

	% Total alcohol	Refractivity observed	Refractivity from ethanol curve	Dif.	Factor	Product = % methonal	Methanol: As made	Methanol: Found by L. & L.
1.	47.41	51.9	88.1	36.2	.99	35.8	35.56	35.42
2.	43.43	62.4	84.7	22.3	.97	21.6	21.71	21.38
3.	25.64	34.2	61.25	24.05	.80	19.2	19.23	19.76
4.	48.86	77.5	89.3	11.8	1.00	11.8	12.21	11.77
5.	17.00	34.0	44.75	10.75	.79	8.5	8.5	8.92
6.	23.92	50.2	58.0	7.8	.79	6.15	5.98	6.48

In order to test this method of analysis we have made up a number of synthetic mixtures of known composition and in every case the methanol found was within a small fraction of 1 per cent of that known to be present. Table III shows results of tests on some synthetic mixtures made by Leach and Lythgoe (op. cit.) and which they used to illustrate their method of analysis. We have recalculated these results by the method here outlined and the values are shown in the table.

It will be observed that with one exception the results as calculated by the method outlined above actually give more nearly the correct per cent of methanol than does the original method of Leach and Lythgoe.

COMPARATIVE EFFICIENCY OF WEHNELT CATHODES IN RESIDUAL AIR AND HYDROGEN

BY

O. B. YOUNG

University of Illinois, Urbana.

ABSTRACT

A Wehnelt cathode, heated to a cherry red, was used in a discharge tube of approximately .03 mm. of mercury pressure. The active material on the cathode was produced by heating Bank of England sealing wax. A 500-volt direct-current generator maintained a steady potential difference across the tube.

First with dry air as the contained gas, the discharge current was measured every fifteen minutes for three hours. Beginning with a value of 2.5 x 10^{-6} amperes, the current decreased at a nearly steady rate to 1.4 x 10^{-6} amperes.

At the end of this three hour period the atmosphere was quickly changed to hydrogen at about the same pressure. The current then suddenly increased almost two thousand times. In a few minutes the discharge decreased to 4 x 10^{-6} amperes. Three minutes later an "explosion" took place at which the current rapidly increased and in seven minutes time reached a value of 31.2 x 10^{-6} amperes. Then as quickly the current decreased to nearly its value before the "explosion." Hereafter the decrease was at the same rate it had been in air.

The above data were taken from a typical curve and were verified by other readings. The conclusions from the investigation are:

(1) Considering the normal decrease in the discharge, the Wehnelt cathode is about three times as efficient in hydrogen as in air.

(2) Explosions are likely to occur soon after the apparent steady condition is reached and not later.

(3) The rate of decrease of the current is not dependent on the pressure within the limits of ordinary vacuua, i. e., between .1 and .001 mm. of mercury.

(4) The tremendous increase in current upon the introduction of hydrogen continues for only a short time and is independent of the pressure.

(5) A small change in the heating current causes a large change in the thermonic current.

(6) Mechanical vibrations increase the discharge.

These observations agree with the results of other experimenters.

The author wishes to express his appreciation to Professor C. T. Knipp for the suggestion of the problem and for assistance in carrying out the details.

ELECTRODELESS RING DISCHARGE—MAGNETIC, INDUCTIVE, AND CENTRIFUGAL ACTION

BY

CHARLES T. KNIPP

University of Illinois, Urbana.

The electrodeless discharge was first studied and exhibited in England some forty years ago. Since then many contributions have been made by physicists and physical chemists throughout the scientific world.

MAGNETIC STUDY

Considerable attention is again being directed to the rôle of the two fields—electrostatic and magnetic—in the production of the discharge within the tube. In March[1] of this year the writer published a number of photographs showing the relative intensities of the magnetic and electrostatic illumination components in the electrodeless discharge produced in a specially designed tube. The method used was to place obstructions in the path of the discharge and from the shadows cast, inferences could be drawn as to which field was responsible for the most intense illumination and, hence, for the discharge. Figures 1 and 2 are photographs showing the two types of discharge. When the time of exposure is taken into account the photographs obtained (only two are here reproduced) show in every instance that the discharge (at any rate that responsible for the most intense illumination) was due to the magnetic field. This experimental result seems to support the view set forth by Sir. J. J. Thomson.

INDUCTIVE STUDY

Another phase of the experimental study of the electrodeless discharge was undertaken by J. K. Knipp and the writer. The measurements contemplated were not, at this writing, completed, although the investigation had been carried far enough to warrant inclusion in this summary. It has long been a question as to what magnitude the current might rise in the electrodeless discharge. Theoretical calculations of this current have been attempted by several investigators, but

[1] Knipp, C. T., Phys. Rev., vol. 37, No. 6, Mar. 15, 1931.

no experimental method seems to have been devised. The method herein described is simple and direct.

It is clear that an inductive method in which the gaseous current would serve as the primary could not be used, since its effect on the secondary would be completely masked by the inductive effect of the energizing coil. This difficulty has been overcome by piping, so to speak, the gaseous current aside through a tube where it is bent into a coil of two turns and then returned to the initial coil which consists of three turns. The circuitous path formed by the re-entrant tube was thus continuous. Figure 3, which is a photograph taken while the dis-

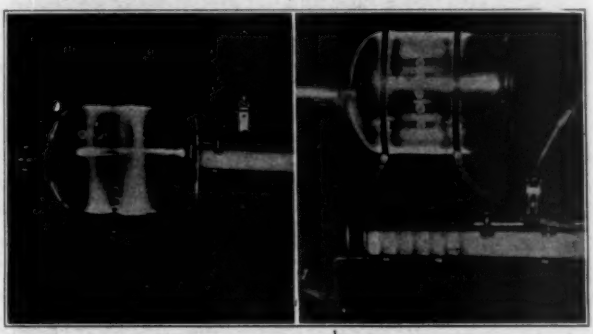


FIG. 1. *(Left)* **Electrodeless ring discharge completely formed when an energizing coil of 8 turns was placed inside the vessel. Illumination intense white; time of exposure 6 seconds followed by a photoflash. Shadows due to obstructions plainly show the path of carriers. No electrostatic effect visible.**

FIG. 2. *(Right)* **Electrostatic discharge only. The band electrodes were placed on outside of vessel as shown and looped across a coil of 8 turns. (This coil was placed on the inside of vessel in Fig. 1.) Illumination a faint purplish-red glow; time of exposure 130 seconds. The direction of the electrostatic field is clearly shown by the shadows cast. The dark region parallel to each electrode is Crookes dark space. Overhead lights to finish exposure.**

charge was passing, shows the relative positions of the two glass coils of the discharge tube. The figure also shows the energizing coil (the primary) carrying the high-frequency current surrounding the electrodeless discharge tube (the secondary) with their planes parallel and at right angles to the plane of the paper. This secondary is not reentrant within the exciting coil, but as stated above, is piped aside and the loop into which it is shaped is given a turn of ninety degrees, as shown, placing its plane in the plane of the paper. This glass coil carrying the gaseous current becomes the *primary* of a low-resistance secondary of one turn of a copper braid conductor placed around it, the terminals of which, in turn, were connected to a radio ammeter as shown in figure 3.

With this arrangement the ammeter, on excitation of the electrodeless discharge, read 4.8 amperes. This magnitude came as a surprise. As the resistance of the secondary (the ammeter circuit) was exceedingly low it is safe to assume that its readings represented quite accurately the gaseous current flowing through the reentrant discharge system. This, as the gaseous current made two turns and the copper secondary but one, would be approximately 2.4 amperes.

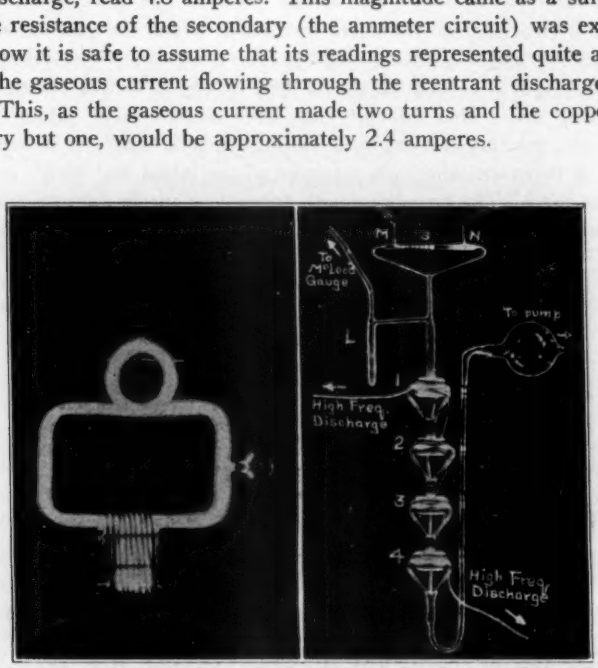


FIG. 3. *(Left)* **Electrodeless discharge in a reëntrant discharge-tube formed by an energizing coil of 9 turns. Secondary within energizing coil consisted of 3 turns of glass tubing which led out through the rectangular shaped circuit to a glass coil of 2 turns. This coil carrying the gaseous current formed the primary, the secondary of which consisted of one turn of heavy copper braid conductor connected to the radio ammeter as shown. The ammeter shows 4.8 amperes. Time of exposure 6 seconds, followed by a photoflash. The pump connection is shown at right.**

FIG. 4. *(Right)* **Special tube to show centrifugal action in the electrodeless ring discharge. Four units are connected in series. The magnification factor is thus four times the effect produced by one unit. The discharge tube MN shows the striae. When the high frequency discharge was turned on the striae at MN moved apart and receded toward M, indicating a reduction in pressure in MN as was expected. Exposure 6 seconds, followed by a photoflash. To get the striae S an additional long exposure was required.**

The generating current flowing in the exciting coil was measured by a shunted radio ammeter, so connected as to correct for inductive effects, and found to be 56 amperes. Thus the gaseous current was about one twenty-third that of the exciting current, an interesting result which it is hoped will be found to agree with theory.

Centrifugal Study

It occurred to the writer recently while working with the electrodeless ring discharge where the discharge tube was blown in the form of a toroid (reentrant) that possibly there might be a centrifugal action of the electrons, in their excursions to and fro, of sufficient magnitude to be observable if proper conditions of experimentation were selected. This was suggested by Professor Nipher's experiments[2] of many years ago, and also by the shadows cast in the magnetic study described above.

On second thought it is evident that the carriers in this case would be confined wholly to electrons, as the heavy ions could not possibly respond to the frequency of 800 k. c. per second that was impressed on the circuit in these experiments. Also it is doubtful, even at the high velocities employed, whether the electrons, although they do travel over a considerable distance (as shown by their shadows) would by reason of their small mass be driven towards the periphery of the toroid. To test this point experimentally a special centrifuging tube was designed, and, to magnify any possible effect, four such tubes were connected up in series.

The complete set-up is shown in figure 4, which is a photograph of the tube while the electrodeless discharge was circulating through it. The four units are shown with an exciting coil of four turns surrounding each. A discharge tube actuated by 1500 volts, small storage cells, was fused to the top to detect a possible change in pressure. A McLeod gauge was also attached. Each unit has three ports leading from the periphery to the center of the unit below. The centrifuged electrons, when the discharge is passing, find their way through these ports and on down to the center of the next unit where the action is repeated. The lower end of the series is connected to the exhaust pump. The optimum pressure for the electrodeless discharge to form is about .2 mm. of mercury. The action, thus, is as follows: with the pressure in the system, as measured by a McLeod gauge, at .2 mm., and the exciting coil *not* in action, the discharge tube at the top showed, on closing the 1500 volt circuit, a definite spacing of the striae. If now the exciting coil is energized the striae should move apart and also shift toward the anode, indicating a reduction in pressure in that portion of the system. This was exactly what took place, showing that the horizontal discharge tube experienced a reduction in pressure. This is an interesting result and is the subject of further investigation.

[2] Nipher, F. E., Science, vol. 28, pp. 93 and 807, 1908; vol. 29, p. 237, 1909.

AN EXPERIMENT TO DETECT A POSSIBLE EFFECT OF A TRANSVERSE ELECTRIC FIELD ON LIGHT

BY

A. P. CARMAN

University of Illinois, Urbana.

In *Science* for February 21, 1930, we proposed a possible explanation of the dielectric action of the ether. In this we assume that empty space is the medium called the ether, by which electric forces are transmitted. The modern theory of dielectrics, developed particularly for gases and liquids by Debye and others, explains the dielectric action as due to "dipoles"; extending this concept to the ether, we think of the ether as containing "ether dipoles." When we have an electric field across the simple ether (empty space), we have these "ether dipoles" lined up, that is, the ether will have a structure, a "grain" in the direction of the lines of electric force.

The following experiment has been devised as a possible means of testing any such ether structure: It consists in brief in sending a beam of plane polarized light across a long electric field maintained in a very high vacuum. The entering beam is polarized at 45° to the direction of the electric field, so that the ether structure, if it exists sufficiently, should produce elliptical polarized light at emergence. The emergent light can be examined by using a second nicol, and noting any change by the eye; but, as the change will be small and possibly uncertain to the eye, it has been arranged to examine the emergent light photographically. For this purpose, we are using a "Memo" camera. In this we have a film such as used for "moving" pictures, each exposure being one inch by three-fourths inch. The film is changed for a new exposure by simply pressing down a lever. The shutter can be set for one twenty-fifth, one fiftieth, or one one-hundredth of a second exposure, and there are four stops for different illuminations, so that it is easy to get a succession of fifty exposures on the strip of film for the same stop and time of exposure. Thus an exposure can be made with no electric field, and a second later with the maximum electric field intensity. Any difference of intensity or of pattern of the transmitted light should then be detected by studying the exposures. This assumes that the "structure" of the ether is not

so fine as to affect the light. It may be that such structure can be detected by some light of ultra short wave length, when light of ordinary wave lengths is not affected. The arrangement of the experiment as it has been set up is shown in figure 1.

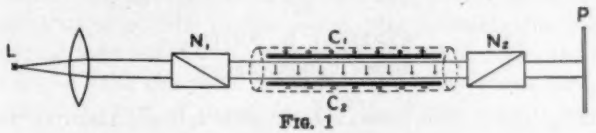


FIG. 1

L is a source of light, a "Pointelite" lamp; the light is made parallel and is polarized by the Glan-Thomson nicol N_1; it then passes between the plates C_1C_2 of the electric condenser; and then through the nicol N_2, and strikes the photographic film at P. The condenser C_1C_2 is enclosed in a vacuum. The electric field is 60 centimeters long, 2 centimeters wide, and the distance between the plates is 2 millimeters.

This experiment has been planned on the assumption of an ether in which light is a wave motion. Within recent years a number of our leaders in physics have returned to a corpuscular theory of light. This is not the place to discuss such phenomena as the photo-electric and Compton effects, which have led to a particle or quanta theory of light. The experiment described above, will, interpreted on this corpuscular theory, afford a test as to whether photons or light quanta have electric moments to be affected by a strong transverse electric field. A recent experiment by Watson at the Cavendish Laboratory (Proc. R. S. June, 1929) has shown these photons have no measurable magnetic moments, so that question of the electric moment of the photon is as important in the quanta theory of light as is the ether structure in the ether theory.

ADDENDUM—**The experiment as described in the paper read before the Academy on May 8, 1931, was arranged also with a sensitive visual polarizing apparatus. It was estimated that a rotation of less than thirty minutes could have been detected with the arrangement, but no effect was observed with an electric field estimated as fully 50,000 volts between the plates of the vacuum condenser. At the time of printing, the experiment was being continued with still more sensitive apparatus.**

A WEDGE-TYPE ACTINOMETER

BY

CLARENCE R. SMITH

Aurora College, Aurora

During some experimental work with various mixtures used as photographic flash powders, the need arose for a method of testing the actinic power without the expensive and more or less elaborate equipment usually employed. For precision work the method ordinarily employed would be to expose a plate and measure the density by means of some form of densitometer.[1] As the work in hand involved light sources of widely differing intensity there was need for a method of wide range. Other desired features were, rapidity of manipulation, and direct reading with little or no calculation. A high degree of precision in results was not one of the requirements. These conditions seem to be satisfactorily met in the method here described.

On a 9x12 centimeter plate was prepared a photographic wedge covering an area 15 millimeters wide and 100 millimeters long with a density range from 0 at one end to a density having a transmission of approximately 1/200 at the other end. This wedge strip was made to come slightly above the center line of the plate so that by reversing ends of the plate, two prints could be made near together with the denser portions at opposite ends. The plate was covered with black paper except for the wedge strip.

If two sources of light at the same distance are used to make two prints of the wedge on the same plate in such a manner that they will be parallel and with reversed ends, there will be a position where the two prints will match in density and the light intensities can thus be compared, unless they differ so greatly as to be "off scale." In the practical use of this wedge, a standard exposure was adopted for one of the wedge prints in every test. In this case, for the standard print, an automobile headlight bulb of the blue variety was used. It was found that an exposure of 20 seconds at 5 volts (much below the rated voltage) and at a distance of 2 meters gave the desired print. For this exposure the calibration of the lamp is of no consequence, the only condition being that a standard print could be made, always of the same contrast.

[1]Huse, Emery. On the Photographic Intensity of Flashlight Materials, Jour. Frank. Inst., p. 391, Sept. 1923.

A calibration curve was next constructed showing the exposure values of various match positions along the standard wedge print when compared with the print of another source. For convenience, the lamp used was the same one mentioned above, but at 12 volts instead of 5. At 12 volts it had been carefully compared with a photometric standard and found to be of 14.9 candle power. By operating the lamp for various time intervals, various test exposures were made, the meter-candle-second value calculated for each, and a curve constructed somewhat similar to that of figure 1. For the curve actually shown in

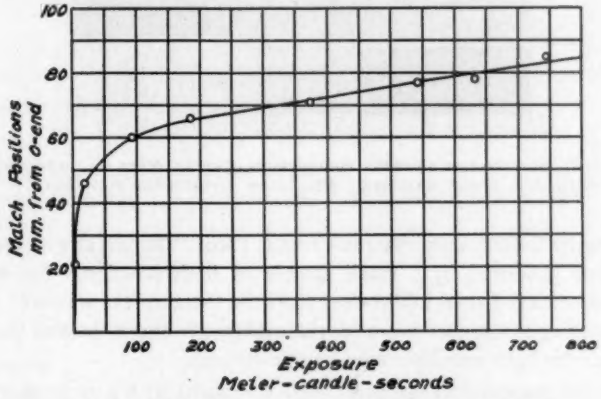


FIG. 1. Calibration curve for wedge with a filter.

figure 1, however, the test exposures (but not the standard prints) were all made through a neutral tint filter having a transmission of about 1/100, as it had been found that for the work in hand the range was otherwise not high enough.

For this work the plates used were Eastman 36 in 9x12 centimeter size. Tray development was used with Eastman formula D-61a, and in every case continued for 6 minutes, the temperature being approximately 65°F. In choosing the automobile headlight bulb, the blue glass variety was selected under the supposition that the closer resemblance of the light quality to that of daylight might be of some advantage. In making the two prints on each plate, of course it is essential that wedge plate and exposed plate always register accurately in the same relative position. This was accomplished by simply taking care to always crowd all plates to the same corner of the printing frame. When the filter was used, precaution was taken to always keep the same corner of this plate also to the same corner of the printing

frame so that possible variations in density over the plate would be accounted for in a constant way in the calibration curve. Match positions were found by sliding along the plate a slit placed perpendicularly to the two strips and long enough to include a narrow cross section of each. Even illumination was provided by a ground glass in front of a lamp.

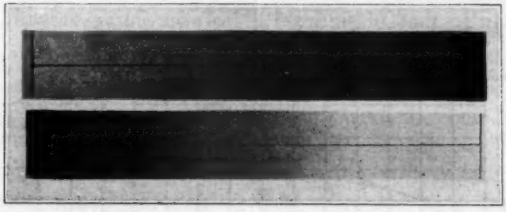


Fig. 2. Sample test showing comparison of print from an unknown light source with that of the standard. The lower strip is the standard.

Figure 2 illustrates how the curve is used. The unknown exposure here was produced by a small sample of flash powder. The match position occurred at 66 millimeters from the 0-end of the standard print, and locating the proper point on the calibration curve showed that the value of the light was 185 meter-candle-seconds.

If the standard wedge print were compared with a strip of merely uniform density, the range of the device would be only that between the two ends of the wedge, whereas by printing the test exposure also through a wedge negative, the range is greatly increased. The effect can be looked upon as equivalent to the use of a series of many different filters.

The curve shown as a sample in figure 1 can be made to present a better appearance by plotting the logarithms of the exposures instead of the actual values and in this form it would resemble more closely the familiar curves used to represent plate characteristics. However for the practical purposes at hand it was desirable to have the graph constructed so that meter-candle-second values could be read off directly and without computation.

A number of variations will suggest themselves for particular purposes. If greater precision were required through a narrow range, it would be better to have a wedge of less contrast and use only the more sensitive part of the curve. Using filters of greater density than that employed here would make it possible to work with greater light intensities. Considerable latitude may also be had by varying the

distance of the light source. In the work actually done, 2 meters was found to be a convenient distance in most cases. If the distance is taken as 1 meter, the readings will be directly in candle-power-seconds, while at other distances the inverse square law must of course be taken into account. Although the method was devised for flash sources of light, it could also be used for continuous sources by exposing for a definite time.

DRY WEATHER OPERATION OF A SEWAGE TREATMENT PLANT

BY

HOWARD W. ADAMS

Illinois State Normal University, Normal.

During the months of July, 1930 to February, 1931, inclusive, the total rainfall in the Bloomington district was 9.89 inches, whereas the average rainfall for these months over a period of more than 35 years has been 20.80 inches, the former being but 47.5 per cent of the normal (fig. 1). July of this period had but 12 per cent of the normal rainfall, August 54 per cent, September 60 per cent, October 73 per cent, December, January and February, 16.5, 11.2 and 4.19 per cent, respectively, and one month, November, had more than the normal rainfall for that month, being 120 per cent.

The limited rainfall has had a marked effect on the operation of the sewage treatment plant of the Bloomington and Normal Sanitary District. By a process of screening, settling, and digestion of solids and aeration of the liquid, the plant is able to affect purification of the water averaging 90 per cent or more. The sewers of the district, serving a population of approximately 30,000, are combined sanitary and storm water sewers, hence in times of heavy rains the volume of the sewage increases materially and continues after such periods of heavy rain because of the seepage of ground water into the sewers. Before the use of treatment works for the scientific purification of sewage, sanitary engineers looked upon the diluting and scouring action of storm water as highly desirable, working for the better operation of the system. Storm water, of course, increases the load the treatment works is compelled to carry.

Because of the diluting action of storm water, and because such waters are relatively stable, it is the practice during periods of excessive flow to by-pass a portion of the water into the stream known as Sugar Creek. During the dry months covered by this report the sewage volume treated by the works, which is the volume pumped, was fairly constant (fig. 1) at about four million gallons per day, whereas the corresponding months of the other years have generally been much higher except for September 1928 when, because of very high rainfall, large amounts were by-passed.

If separate systems of sewers were in use, one designed to carry storm water and the other sanitary sewage, storm waters could be sent into the water courses without treatment, and only the sanitary sewage would need to be treated, thus reducing operating costs. The volume of sanitary sewage of the district is about four million gallons daily.

The relationship of suspended solids and rainfall is shown in figure 2. Increased rainfall and increased volume of sewage are not always accompanied by an increased amount of suspended solids, as is evident from a consideration of the unusual rainfall in July, 1929, accompanied by a low amount of suspended solids, a condition repeated in January, 1930. Prolonged and heavy rains are likely to wash sewers and pavements of accumulated solids, so that high volume is likely to be accompanied by low suspended solids. The unusually high suspended solids of November and December, 1928, and again for the same months in 1929 are accompanied by rainfall of normal amounts or less, together with a heavy inwash of leaves and such rubbish from pavements.

The low rainfall of 1930-1931 has been accompanied by fairly uniform suspended solids, making for uniform load on the plant and good operating conditions. November and December of this period did not bring the peak of suspended solids as in the two previous years because the dry weather permitted burning rubbish on the pavements.

Removal of suspended solids by the Imhoff tanks (fig. 3) averaged 73 per cent during the dry months, while the removal for the corresponding months of the other years averaged 68 per cent, showing the increased efficiency of the Imhoffs when operating under a fairly uniform load of solids from sanitary sewage. Likewise removal of solids by the entire works was greater during the dry months.

Oxygen consumed (fig. 4) is measured by the hot potassium permanganate method, using sulfuric acid. Dilution of the sewage with storm-water diminishes the oxygen consumed, whereas a more concentrated sewage has a higher oxygen consumption. In general the oxygen consumed rises as the winter months approach. The low oxygen consumed in July, 1929, is doubtless due to the diluting action resulting from the abnormal rainfall in that month. The September following was marked by a low rainfall, hence the oxygen consumed rises sharply and doubtless would have maintained that general level had it not been for more than average rainfall coupled with a pumpage higher than average. These factors indicate diluted sewage, hence descending oxygen consumption during the months October to February.

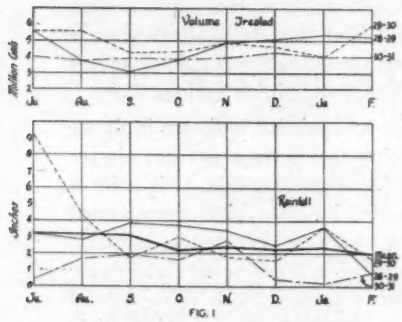


FIG. 1

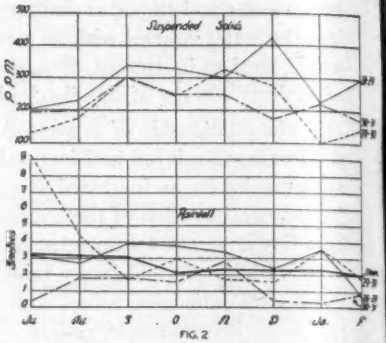


FIG. 2

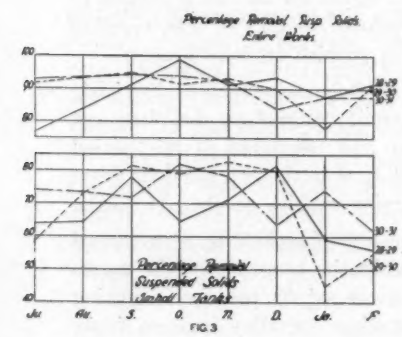


FIG. 3

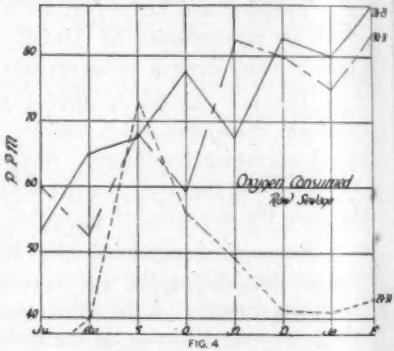


FIG. 4

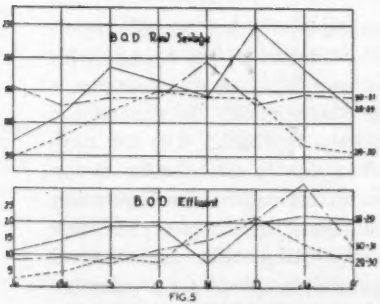


FIG. 5

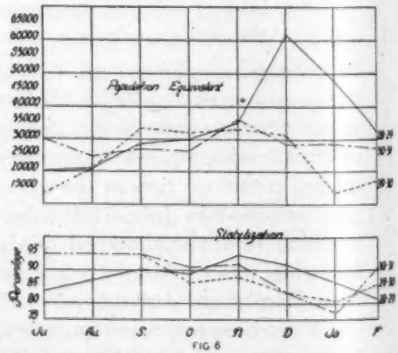


FIG. 6

Figs. 1-6. Graphs showing (1) relation of rainfall to volume of sewage treated, (2) relation of rainfall to suspended solids., (3) removal of suspended solids, (4) oxygen consumed, raw sewage, (5) biochemical oxygen demand, and (6) percentage stabilization and population equivalent.

Biochemical oxygen demand measures the oxygen requirement of sewage samples when incubated for a five day period at 20 degrees centigrade. It will be observed that the dry months of 1930 and 1931 (fig. 5) had a fairly constant biochemical oxygen demand, while the months for the other years had fluctuating biochemical oxygen demand values. Likewise the plant effluent had a constant biochemical oxygen demand during 1930 and 1931 except for the months of December and January, when the high values were induced by a necessity of plant operation, while the corresponding months of the other years show considerable fluctuations.

The stabilization of the sewage (fig. 6) which is the ratio of the biochemical oxygen demand of the raw sewage to that of the effluent, was generally better for the dry months, preceding winter, than for the corresponding months of the other years.

The population equivalent, which is calculated from the biochemical oxygen demand of the raw sewage, is more uniform for the dry months, being about 30,000, than for the months having unusual rainfall.

In conclusion, it is apparent:

1. That the dry months of 1930-1931 had so little rainfall that the plant operated on practically sanitary sewage only.

2. That substitution of sanitary sewage for combined sewage would reduce operating costs by decreasing the volume of sewage to be pumped.

3. That the suspended solids in sanitary sewage are more nearly uniform than in combined sewage.

4. That the Imhoff tanks show a uniform removal of suspended solids as against the greater fluctuations produced by combined sewage, and likewise the removal of solids by the entire works is uniformly better for sanitary sewage than for combined.

5. That the instability of the sewage as measured by oxygen consumption and biochemical oxygen demand are more uniform for sanitary sewage than for combined.

6. That the diversion of storm water into water courses would be desirable, thus separating it from sanitary sewage, which separation would make possible more uniform and better operating conditions of the treatment works.

The writer wishes to express his appreciation to the Board of Trustees of Bloomington and Normal Sanitary District and to Mr. Harry E. Wilson, Superintendent, for the opportunity and means of making the study.

CLASSIFICATION OF RESEARCH PROBLEMS ON DIELECTRICS WITH SPECIAL REFERENCE TO THE INVESTIGATION OF CABLES AND CONDENSERS

BY

J. Tykocinski Tykociner and E. B. Paine

University of Illinois, Urbana

Introduction

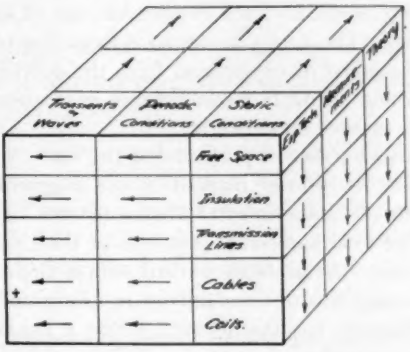
Since autumn, 1926, a cooperative research on cable testing is being carried out at the Engineering Experiment Station of the University of Illinois. In the early stages of the investigation it was realized that in spite of the limitations set by the specific technological character of this research project, the problems involved embrace a vast field of the science of dielectrics. Cables represent special cases of complex forms of condensers whose dielectric is the seat of important processes. Rational methods of cable testing could hardly be developed without a deeper knowledge of the physical and chemical changes which take place in dielectrics under the action of intense electric fields. A review of our knowledge of related phenomena revealed the necessity of extensive research in fundamental properties connected with the deterioration and final breakdown of dielectrics.

Dielectrics

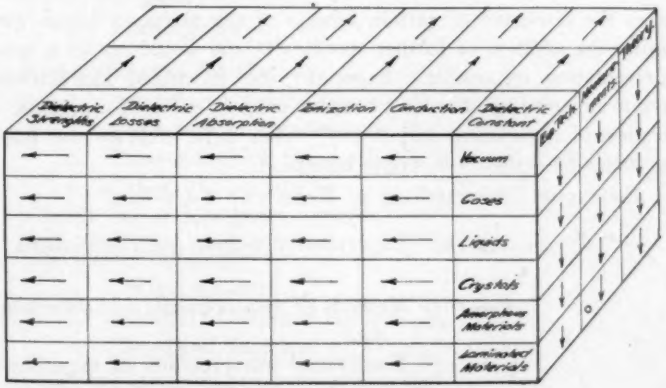
In order to evolve a general plan of research in connection with dielectrics, an attempt was made to unify the multifarious problems in the form of a systematic classification. Specific problems when viewed from the standpoint of an expert may appear disconnected from other problems, yet they may be so interconnected that their solution requires the cooperation of mathematical physicists, experimental physicists, chemists, and research engineers. Cooperation is necessary in most of these investigations in order that a working theory of the dielectric phenomena may be gradually constructed on the basis of the knowledge of correlations to be discovered in all the allied branches of research. Experience has shown that research thus organized often leads to the solution of vital engineering problems.

A simplified diagrammatic picture of the entire field of problems may be obtained by dividing them into two classes. As shown on the accompanying diagram, class A refers to problems of distribution of

Classification of Dielectric Research Problems.



A. Problems of Distribution of Electric Forces.



B. Problems of Insulation and Properties of Dielectrics.

FIG. 1

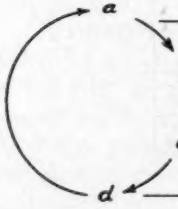
electric and magnetic forces. Class B refers to problems of insulation which require the investigation of the properties of dielectrics. Each class is represented by a coordinate system in form of an imaginary filing cabinet which contains along its three axes drawers assigned to

particular problems. In accordance to the three basic elements, that is, phenomenon, medium, and method, in every investigation, each drawer carries three inscriptions. In the direction of the x-axis follow the inscriptions of the phenomena investigated. Each drawer carries on the top the inscription of one of these phenomena. The y-axis is assigned to inscriptions of the characteristic medium, where the phenomena were studied. Each drawer has one of these media inscribed on the front. The z-axis serves to indicate the sequence of stages in a scientific method of exploration from the development of an experimental technic through measurements to theory. Each drawer is accordingly marked on the right.

The total number of problems of the class A thus obtained is 45. For example, the drawer marked on the diagram by a cross signifies the problem of "Experimental Means for the Study of Waves in a Cable." The total number of problems of the class B amounts to 108. So for instance the problem marked with a circle pertains to "Quantitative Investigation of Conductivity in Laminated Materials."

The diagram has the advantage that a considerable part of the domain of dielectrics may be thus reviewed at a glance. However, such a simplification was arrived at by sacrificing the completeness of the picture. The limitation set by the use of only three coordinates forces the disregard of certain aspects of the problems which would require the addition of further coordinates and would render a spacial representation impossible. Especially the functional characteristics have to be considered from a broader point of view of a periodic application of experiment and theory. They must embrace the following stages of research in cyclic repetition.

Functional Characteristics of Research: (*a, b, c, d*)



(*a*) Experimental technic and observations

(*b*) Methods of measurements and collection of data

(*c*) Theory and interpretation of experimental results

(*d*) General review of the situation and prediction of new phenomena

The functional characteristics are common to every systematic research work and have to be included in all classes of problems. They may be pictured as the consecutive steps along a spiral around which every scientific problem has to progress, moving upwards towards its solution.

For a more complete classification it is suggested to divide the entire field of dielectric research into five classes denoted by I, II, III, IV and V.

I. Problems of distribution of electric potentials and currents.
II. Problems of distribution of temperature and thermal flow.
III. Problems of distributions of mechanical stresses and deformations.
IV. Problems of insulation and physical properties of dielectrics.
V. Problems of chemical transformations and of changes in the properties of dielectrics.

I. Problems of class I relate to the distribution of electric potentials and currents. In this connection the time-space relations of the acting electric and magnetic fields (A, B, C, D), the configuration of the medium (1, 2, 3, 4, 5), the character of the medium (a, b, c) and the functional characteristics of research *(a, b, c, d)* have to be considered.

Time-space relations of the acting electric and magnetic fields:

A. Static conditions
B. Periodic conditions
C. Transient conditions
D. Standing waves

Configuration of the Medium:

1. Pointed or spherical boundaries (spark gaps)
2. Plane-parallel (condensers)
3. Plane-cylindrical (transmission lines and cables)
4. Cylindrical boundaries
5. Spiral boundaries (coils)

Character of medium:

a. Perfect dielectric
b. Imperfect uniform dielectric
c. Laminated dielectric

Using the above five groups of notations

I
A B C D
1 2 3 4 5
a b c
a b c d

we obtain by combination 1x4x5x3x4=240 problems or tasks. So for instance the problem denoted by ID4c*b* refers to "Methods of

measuring standing waves in a cable composed of a laminated dielectric." The problem denoted by IB2b*a* refers to "Experimental technic for the study of the distribution of electric potential in a condenser composed of a uniform dielectric."

II. Problems of class II relate to distribution of temperature and to thermal flow. In view of certain analogies problems of this class may be classified similarly to those of class I.

III. Problems of class III are concerned with the distribution of mechanical stresses and deformation, and by analogy are also related with the distribution of electric potentials. They may be also classified similarly to those of class I.

IV. Problems of insulation belong to class IV. They are directly connected with physical properties of dielectrics and aim principally at the discovery of co-relations which may exist between the following three distinct groups of physical factors.

Factors connected with the distribution of different forms of energy in a dielectric:

A. Dielectric constant
B. Conductivity
C. Ionization
D. Electrostriction
E. Dielectric absorbtion
F. Dielectric losses
G. Dielectric strength

Factors determining the structure of a dielectric:

1. Vacuum
2. Gases
3. Liquids
4. Crystals,
5. Amorphous materials
6. Laminated materials
7. Textile materials

Agencies which influence the dielectric:

a. Intensity of applied potential
b. Duration of applied potential
c. Wave form of applied potential
d. Frequency of applied potential
e. Action of magnetic flux
f. Action of thermal agitation
g. Action of radiations
h. Mechanical action.

By including the functional characteristics of research *(a, b, c, d)* we may assemble the above groups of notations as follows:

IV.
A B C D E F G
1 2 3 4 5 6 7
a b c d e f g h
a b c d

and obtain by combination 1 x 7 x 7 x 8 x 4 = 1568 problems. For instance, IVE3d*c* denotes a problem on the "Measurement of the influence of frequency on the dielectric absorption of liquids." The problem denoted by IVG2g*d* may serve as another example. It signifies "Theory of the action of ultraviolet radiations on the dielectric strength of gases."

V. Class V of problems refers to transformations which take place in the dielectric under the influence of electric fields and to lasting changes which are produced in the properties of dielectrics by various agencies.

Here again all the factors of Class IV are considered but under conditions which cause a deterioration in the structure of the dielectric.

Furthermore a series of four additional agencies, electro-chemical in origin, are included, *i. e.*,

Q. Bombardment of electrons and ions.
R. Action of impurities.
S. Electrolytic action.
T. Chemical processes.

The entire group of notations for Class V is as follows:

V.
A B C D E F S
1 2 3 4 5 6 7
a b c d e f g h
Q R S T
a b c d

The number of problems is given by the product 1 x 7 x 7 x 8 x 4 = 6272. For instance, the notation IVG5aS*d* signifies "Quantitative determination of deterioration affecting the dielectric strength of amorphous materials subjected to electrolytic action at high potentials."

The problem VB7gT*d* may be described as "A critical study of results of investigations on the chemical processes causing deterioration as observed by increasing conductivity of textile insulating materials subjected to the action of ultraviolet radiation."

The classes as well as the groups in each class may be extended, also sub-groups may be added in order to limit each investigation to specific kind of materials or to specific sets of conditions. In providing

these divisions and subdivisions the following principle shall be adhered to: Proceed logically from the simpler to the more complex materials or phenomena respectively, so that by consecutive combinations of the notations, problems may be indicated in the order of their fundamental importance. It should also be kept in mind that the purpose of the classification is three-fold:

1. To give a perspective of the entire field.

2. To show to the investigator lost in details of his labors the channels uniting his work with the greater problems.

3. To facilitate the setting up of a general plan of attack on the problems of dielectrics.

Cables

When we turn our attention to the specific problems of cable investigation we find ourselves confronted with a still greater complexity of materials, forms, and conditions. The simplified conditions we usually attempt to establish for our purely physical investigations appear as mere idealizations when we start experimental or theoretical investigations of cable problems.

The factors enumerated in the foregoing classification must be extended to include technological conditions and processes. Of all factors the following must be considered as the most important:

A. Materials entering into the construction of a cable

B. Phenomena which are involved in the process of manufacture

C. Phenomena which are involved in the installation

D. Phenomena which are involved in the operation of the cable.

A. *Materials Entering into the Construction of Cable and the Properties of Each Material Which May Influence Cable Quality:*

a. Lead—Chemical composition, percentage of alloying elements, etc.
Physical constants such as density, ductility, strength, etc.

b. Paper—Chemical properties.
Physical properties.

c. Compound—Chemical properties.
Physical properties.

d. Copper—Chemical properties.
Physical properties.

B. *Phenomena Which are Involved in the Process of Manufacture and Affect the Properties of Cables:*

a. Mechanical problems.

(1) Influence of tension of the paper.

(2) Effect of overlapping and registration.

(3) Effect of pressure and temperature produced by the lead press.

b. Problems of drying.

How does the rate of drying affect the properties of the paper.

c. Problems of impregnation.

(1) Methods of measurement of the degree of impregnation.

(2) Effects of time, temperature, and pressure on the degree of impregnation.

(3) Detecting and locating places of imperfect impregnation.

d. Problems of testing.

How does the application of over-voltage affect the properties of a cable.

C. *Phenomena which are involved in the installation of cables.*

a. Problems of changes produced by pulling.

b. Problems of changes produced by bending.

c. Problems of changes produced by splicing.

D. *Phenomena which are involved in the operation of a cable:*

a. Thermal.

b. Electrical.

c. Magnetic.

d. Chemical.

a. Thermal problems.

(1) Expansion effects on sheath insulation and conductor, formation of voids, pressure, etc.

(2) Deterioration of cable materials due to heat.

(3) Heat flow from points within cable where heat is produced and the resulting temperature. Heat flow from cable itself into ducts and surrounding region.

(4) Effect of temperature on properties of cable material; relation between temperature and the various losses.

b. Electrical problems.
   (1) Why does the dielectric break under voltage stress?
   (2) How is the electric stress distributed in impregnated paper insulation?
   (3) Discharges in gas-filled spaces; under what conditions do they occur, what circuit effects do they produce? What chemical changes result? What energy losses, etc?
   (4) What is the nature of dielectric loss? What is the relation between dielectric loss and the various factors which influence it?
   (5) Changes in compound due to ionic bombardment. What is the substance called "X"? Under what conditions is it produced?
   (6) Variation of dielectric loss in cable insulation with temperature.
   (7) Surges and their effect on the deterioration of cables.

c. Magnetic problems.
   (1) Influence of magnetic flux on electrical discharges.
   (2) Influence of magnetic flux on dielectric losses.
   (3) Influence of magnetic flux on dielectric strength.
   (4) Mechanical forces produced between conductor and sheath and between surrounding cables.
   (5) Losses in sheath and conductor produced by varying magnetic fields.

d. Chemical problems.
   (1) Stability of compound under electric stress, increased temperature, etc.
   (2) Relation between chemical properties of compound and ability to withstand voltage stress, the magnitude of dielectric losses, the specific inductive capacity.
   (3) The relation between chemical properties of compound and the physical properties such as viscosity, capillarity, etc.
   (4) Influence of gases either in solution or in bubbles on compound, oxidation, etc.

(5) Influence of moisture or other impurities on chemical stability and on electrical phenomena, losses, etc.

The growing economic significance of power transmission and the important rôle of cables in the distribution of electric energy makes a thorough research on cables imperative. There is no doubt that the number of publications on dielectric research will steadily increase. Soon it will become necessary to extend the Dewey decimal system of bibliographical notations to the new fields of dielectrics and their applications. It is hoped that the material included in this paper will be helpful also in this connection.

AN EFFICIENT HYDROGEN SULFIDE GENERATOR

BY

JAMES H. RANSOM

James Millikin University, Decatur, Illinois

The construction and functioning of the hydrogen sulfide generator are nearly or quite self-evident from the accompanying sectional view which shows the parts and connections (fig. 1). Experience has shown that a two-gallon aspirator bottle filled with iron sulfide moulded sticks will furnish hydrogen sulfide to a class of thirty-five to forty students for a college year. Full concentrated hydrochloric acid, or somewhat diluted and cooled sulfuric acid may be used, and because it remains in contact with the iron sulfide for a considerable time, the solution becomes practically exhausted of the acid, resulting in the highest possible efficiency for both the acid and sulfide.

The pressure of the gas may be regulated by mounting the acid reservoir on the ring of a heavily constructed, long upright ring-stand, as shown at the right of the figure. The flow of gas may also be regulated by placing in the rubber tube near the service pipe a short piece of thermometer tubing of the proper size to fit snugly and flattening one side with a file to let the gas pass at the desired rate. This is much more satisfactory than the use of a screw clamp on the rubber tubing where the students may manipulate it at will and always with a too rapid flow of gas. The student may not even know that there is a regulator in the system.

The service tube is made from one-half inch bore galvanized iron nipples about ten inches long, connected by T joints into which are screwed pet cocks or faucets for the delivery of the gas. The number of nipples and openings may be regulated depending upon the number of students to be served. We have found that ten or twelve openings are sufficient for a class of thirty-five. To each faucet is attached a short piece of rubber tubing to which is connected a two-inch piece of glass-tubing carrying a one-hole stopper of the size to fit a half liter pyrex Erlenmeyer flask. We have found it convenient to have a couple of the stoppers of a size to fit an ordinary test tube so that students may test samples of their solutions with the gas.

The service tube may be mounted on a table or vacant laboratory desk with weighted ring-stands, and to the proper height so that when

the stopper is in place in the flask the latter will just reach to the top of the table. During the passage of the gas the flask should be vigorously shaken, and occasionally opened for a second to allow the escape of air or other inert gas. As the gas is under pressure, the reaction is quite rapid and complete. The whole apparatus should be mounted

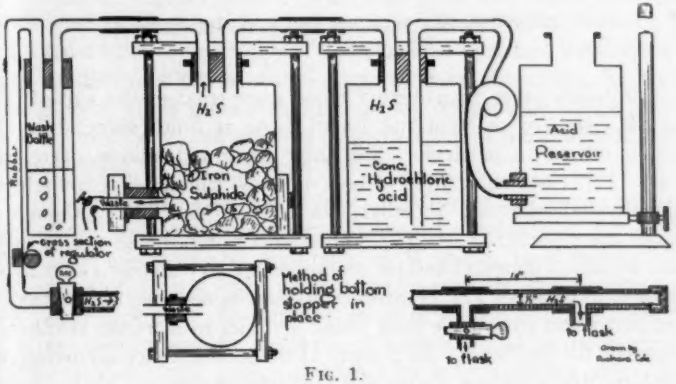


FIG. 1.

to such a height that the spent liquid may be drawn from the generator, as indicated, and conveyed to the drain pipes through rubber or glass tubes.

The unique feature of the generator lies in the method by which all the stoppers are forced solidly into place and kept there indefinitely. No leakage through the stoppers can occur even after long use, and consequently there are no troublesome breakdowns or faulty functioning for months at a time.

DI-ISOPROPYL ETHER AS A SOLVENT IN THE GRIGNARD REACTION

BY

F. H. RATHMANN and J. A. LEIGHTY

Solvents other than diethyl ether were tried in the earliest days of the Grignard reaction and found to be at times successful. The higher ethers, in particular di-isoamyl ether and anisole, were early used. Ether-like substances such as dimethyl sulfide, dimethyl selenide, dimethyl telluride and dimethyl sulfone have been used although the yields are reported as low [1]. Other authors report the use of quinoline, pyridine, dimethyl aniline, and other tertiary amines either as solvents or as catalysts [1]. Hydrocarbons such as benzene, toluene, xylene, and petroleum ether have been found at times to increase, at others to decrease, the yields [2]. In a study of the luminescence occurring during Grignard reactions, Evans and Diepenhorst used as solvents for the reagent diethyl, dinormal propyl, di-isopropyl, dinormal butyl, dinormal amyl, di-isoamyl, diphenyl, resorcinol, dimethyl, methyl phenyl (anisole), ethyl phenyl (phenetole), benzyl ethyl, alpha naphthyl methyl, alpha naphthyl ethyl, alpha naphthyl isoamyl, beta naphthyl methyl, beta naphthyl ethyl, beta naphthyl isoamyl ethers, and di methyl aniline. Tschelinzeff reports the use of paracymene and of other hydrocarbons of the terpenic, aromatic, and aliphatic series [3]. The Grignard reagent was insoluble in benzene although the yield was high. Other substances reported as used were ethyl normal propyl ether and ethyl normal propyl sulfide, 1, 3 dioxan, 1, 4 dioxan, 1, 4 di thian, di isoamyl sulfoxide, diphenyl sulfoxide, diphenyl sulfone, and even carbon tetrachloride [4].

In very few cases, however, do the authors report definite yields, and in most cases no comment whatever is offered as to the yields.

Majima and Kotake [5] studied the relative yields in the case of indole magnesium iodide using diethyl ether and anisole, finding that the former solvent is better when the Grignard reagent is allowed to react with acyl halides while the latter is better in reactions with aldehydes and ketones. Thus indole magnesium iodide with benzaldehyde gives respectively 20 per cent and 61.6 per cent while with acetyl chloride the yields are respectively 93 per cent and 61 per cent in the two solvents.

Gilman and McCracken [2] studied the effect of hydrocarbon ethyl ether mixtures, finding that the yields of Grignard reagent were reduced by addition of hydrocarbon from 10 to 30 per cent in some cases and increased 5 per cent in other cases.

Marvel and Blomquist [6] made quantitiative studies of the yields of Grignard reagents in dinormal butyl ether and found that these yields were equal or nearly equal to those obtained when diethyl ether was used as the solvent. They recommended dinormal butyl ether in place of diethyl ether, in many cases citing as advantages its higher boiling point which gives a higher reaction temperature and a greater recovery of solvent, and the ease of preparation of the anhydrous compound without the use of sodium metal.

As di-isopropyl ether has become an article of commerce, the authors believed that it might be more successfully substituted for diethyl ether than might dibutyl, inasmuch as it should have some of the advantages of dibutyl ether without the excessively high boiling point and rather high cost. Di-isopropyl ether at present sells for about ten to fifteen cents a pound. Recovery of solvent would be much greater, and the danger of fire much less than in the case of diethyl ether. However, so far as our results go at present, di-isopropyl ether does not measure up to the hopes we hold out for it.

The di-isopropyl ether was the commercial grade put out by the Carbide and Carbon Chemicals Corporation and contained according to the specifications only very small amounts of isopropanol. This product was purified in three ways; first, by washing with saturated sodium chloride three times, drying over calcium chloride, distilling, drying, over metallic sodium, and distilling, collecting the 67-68° fraction; second, by washing six times with water, drying over calcium oxide, filtering, drying over sodium and using directly; third, washing three times with eight normal sulfuric, twice with saturated sodium chloride, twice with three normal sodium hydroxide, drying over burnt lime, distilling, refluxing over sodium, distilling and collecting the fraction 67-68° (practically 100 per cent came over in this fraction). So far as our work shows, these three methods are equivalent.

Methyl iodide and magnesium failed to react in di-isopropyl ether in the presence of a crystal of iodine in spite of heating and shaking over a period of several hours. Hepworth reports a similar result using benzene as the solvent [4].

Ethyl iodide reacted well at first with magnesium in di-isopropyl ether but a white solid was formed which soon coated over the magnesium. 7.8 grains (1/20 mole) of ethyl iodide was refluxed with 1.4

grains magnesium in 25 cubic centimeters of the ether for an hour or more after reaction had started. The mixture was then made up to 50 cc. of which 10 cc. taken out for titration required 4.5 cc. of half normal hydrochloric acid. This corresponds to a yield of 22.5 per cent of the theoretical quantity of Grignard reagent. In diethyl ether the yield was 86 per cent and in dibutyl it was 75 per cent.

The reaction of 1/20 mole portions of ethyl bromide was tried in ethyl, isopropyl, and butyl ethers as solvents. The yield of ethyl magnesium bromide was determined by the acid titration and the gas evolution methods [7]. In case of isopropyl ether, a mercury seal mechanical stirrer was used to shake off the white coating forming over the magnesium; the other two were run without the stirrer.

	Diethyl ether	di-isopropyl ether	dibutyl ether
	Per cent	Per cent	Per cent
Acid titration	75, 85, 88	67.5	74, 75
Gas evolution	49, 55	33	38

Isoamyl iodide and magnesium started to react in isopropyl ether but the magnesium soon became coated over with an adhesive layer and reaction ceased in spite of shaking and heating.

Brom benzene and magnesium and isopropyl ether with a crystal of iodine were shaken together for several hours without evidence of reaction. Even after the first signs of reaction appeared, the action did not go on. A 1/20 mole reaction mixture in a three neck flask fitted with a mercury mechanical stirrer was started by means of some previously prepared ethyl magnesium bromide. Soon the magnesium became coated with a black solid. After stirring and refluxing for nearly three hours, the yield of Grignard reagent as found by acid titration to be only '34 per cent.

Dimethyl ethyl carbinol and ethyl phenyl carbinol were prepared by the action of one-tenth molar quantities of acetone and benzaldehyde or the Grignard reagent prepared from one-tenth molar quantities of ethyl bromide in ethyl ether and in isopropyl ether. In both cases the yields obtained from the latter solvent were considerably less than half those obtained from the former.

From this preliminary study it seems that di-isopropyl ether is not a suitable solvent for the Grignard reaction. The authors intend to study the question further.

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6. MARVEL, BLOMQUIST, and VAUGHN, J. A. C. S., vol. 50, pp. 2810-2, 1928.
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PAPERS IN GEOLOGY

EXTRACT FROM THE REPORT OF THE SECTION CHAIRMAN

In the meeting of the Geology Section the following papers were read but were not presented for publication:

"Fossil Holothuroidea," by Carey Croneis and John McCormack, University of Chicago.

"Accumulation of Oil in Limestone," by V. M. Howard, University of Illinois.

"A Pre-Cretaceous Soil Horizon in Western Illinois," by A. H. Sutton, University of Illinois.

"Age of the Black Shale in South Central Kentucky," by T. E. Savage and A. H. Sutton, University of Illinois.

"Another Huronian Unconformity in Northeastern Minnesota," by Virgil Sleight, Northwestern University.

The following papers were read by title only:

"Some Peorian Loess Deposits," by M. M. Leighton, Illinois State Geological Survey.

"Some new Species of Corals from the Niagaran Strata of the Hudson Bay Region," by Denard Lee, Illinois State Geological Survey.

"Ruins and Pictographs in Nine Mile Canyon, Utah," by Albert B. Reagan, Ouray, Utah.

"A Plea for the Cahokia Mounds," by Warren K. Moorehead, Phillips Academy, Andover, Massachusetts.

The attendance at the meeting ranged from 75 to 100.

Dr. T. E. Savage, University of Illinois, was elected chairman of the section for the following year.

(Signed) JOHN R. BALL, *Chairman.*

REVIEW OF AMERICAN COAL BALL STUDIES

BY

A. C. NOÉ

University of Chicago and Illinois State Geological Survey.

In Autumn, 1922, I wrote a letter to Dr. David White informing him that coal balls had recently been found in Illinois, and at a conference during the Christmas vacation of the same year, I showed a sectioned coal ball to him. This was the first coal ball observed in Illinois. It had been collected by Dr. Gilbert A. Cady in the O'Gara mine number 9 near Harrisburg. When the concretion, which looked like an ordinary impurity of the coal, had been left by Dr. Cady with the Illinois Geological Survey and was shown to me by Dr. Harold E. Culver, I recognized it as a coal ball, took it into my laboratory, and cut it with a diamond saw. This was the first known coal ball found in North America and recognized as such.

In December 1929, Dr. David White showed me some concretions taken out of a coal seam in 1910 which undoubtedly can be called coal balls, but which were not recognized as such at the time. Also the fossiliferous structure from the Waverly shales of Kentucky, which E. C. Jeffry described in collaboration with D. H. Scott, are not coal balls, nor are the Lepidostrobus cones which were described by J. M. Coulter and W. J. G. Land in the Botanical Gazette, Vol. 51, 1911.

A great deal of additional coal ball material was collected at the O'Gara mine number 9. Numerous other deposits of coal balls were found in succeeding years in the strip mines of southern Illinois and western Indiana and in various shaft mines, especially in the mine of the Hegeler Zinc Company at Danville, Illinois.

This material is being studied by the author and various of his former students and several of his friends. Also quite a number of coal balls had been sent in the form of exchanges to various scientists in this country and abroad and the author's hope that an ever-increasing number of people would study the coal balls of America is gradually being gratified.

The general policy of the growing group of paleobotanists who work on America coal balls is to concentrate work on individual genera, with the result that the main genera are well-represented in a series

of papers which have appeared primarily in the Botanical Gazette, the Journal of Geology, the Transactions of the Illinois State Academy of Science, and the Mid-west Naturalist. A comprehensive study of the subject with numerous contributions by the author and by his collaborators in this field will appear in the near future as Monograph No. 2 of the Illinois State Geological Survey. It is an attempt to give the result of all previous investigations on coal balls from Illinois, Western Indiana, and Western Kentucky, and to add a number of new discoveries and studies. New material is constantly investigated and new facts are brought to light. Although there are convenient stopping points where a portion of the material may be brought to a conclusion, if we consider the enormous wealth of the available material, we can easily see that it will take a long number of years before we obtain full knowledge of the coal ball flora of Illinois, west Kentucky, and Indiana.

The size of the coal balls found in this field varies between that of a pea and that of a pumpkin. They are usually covered by a brittle and lustrous layer of coal and consist of a dark brown mass of calcium carbonate mixed with mangan and iron. Enclosed plant remains appear distinctly when the coal balls are examined in thin sections or with the help of the cellulous film method. They can be made visible to the naked eye with the help of chloric acid.

The distribution of the coal balls in a seam is sporadical. Sometimes they appear in large banded zones, sometimes irregularly in nests and are usually surrounded on all sides by coal.

The coal balls of Illinois, Indiana, and Kentucky seem to be restricted to a few horizons. These are coals 5, 6, and 7 in Illinois, coals 2, 5, and 6 in Indiana, and coals 9, 11, and 12 in Kentucky.

Even delicate plant organs are excellently preserved, as shown in the thin sections. For this reason, the coal balls must have been formed at the time when these organs were not yet decomposed and had not been compressed by overlying sediments. As the coal balls are found only in coal beds immediately overlain by marine sediments, the presence of marine water must have been necessary for their formation, and indeed the excellent preservation of delicate plant organs can be explained by the preserving quality of sea water. We must assume that the coal balls represent peat masses which petrified gradually, not suddenly, the plant organs being preserved in the concretions while the unprotected portions of peat were coalified.

Microscopic investigations of the coal ball has resulted in the identification of a number of Pennsylvanian plant species. These are:

Lycopodiales:
- **Lepidodendron selaginoides**
- **L. harcourti**
- **L. hickii**
- **Lepidocarpon lomaxi**
- **Lepidostrobus sp.**
- **Lepidodendron (spores)**
- **Sigillario (stem)**
- **Stigmaria ficoides**

Articulatales:
- **Arthropitys communis**
- **Calamosstachys oldhamia**
- **Sphenophyllum plurifoliatum**

Filicales:
- **Botryopteris forensis**
- **B. tridentata**
- **Botryopteris (petioles)**
- **Ankyriopteris (petioles)**
- **Etapteris lacattei**
- **Scolecopteris (sporangia)**
- **Sturiella (sporangia)**
- **Ptychocarpus**
- **Pteridotheca**
- **Psaronius (stem)**

Pteridosperms:
- **Medullosa (roots)**
- **Myeloxylon**
- **Lagenostoma lomaxi**
- **Trigonocarpus**

Cordaitales:
- **Cordaites sp.**
- **Cardiocarpon**

The structures of the plant organs contained in coal balls allow us to draw conclusions upon the climatic conditions of Illinois during the Pennsylvanian period. The tree flora, consisting of Cordaites, Sigillaria, and Lepidodendron, had a more or less xerophytic appearance adapted to a dryer climate, whereas the ground flora, consisting of ferns, tree ferns, and pteridosperms, distinguished itself by hydrophilic characters or adaptation to a moist and hot climate. We find this combination of two opposed types in the modern tropical rain forests.

If we turn to the anatomy of the stems of Pennsylvanian plants we are struck by the almost complete absence of annual rings. This indicates a uniform climate without seasonal changes of temperature and moisture. The conclusion which we may draw from the structure of these plants upon the climate of that period in Illinois are, (1) it must have been warm but not necessarily tropical, (2) it must have been very moist, and (3) it must have been very uniform during the entire year.

The outstanding morphological results of American coal ball investigation are the addition of a few new species, especially ferns, and a better knowledge of the anatomic structure of paleozoic seeds. The largest seeds whose structure is preserved have been found in the Illinois and Indiana coal balls and some uncut material still promises to give us more information on seed structure. It is to be hoped that we may find in one of these beautifully preserved seeds an embryo. No paleozoic embryo has yet been found and it would be a monu-

mental discovery if we could produce the first paleozoic embryo. Another very interesting discovery was the correlation of some external leaf type with the inner structure and the sporangium structure of such leaves.

We are still at the beginning of our knowledge of anatomic structure in American paleozoic plants and it will be many years before knowledge of the subject will be fairly complete.

SOME PLANT STRUCTURES OF COAL*

BY

LOUIS C. MCCABE

State Geological Survey, Urbana

INTRODUCTION

The constituents of coal as a rock have long been of interest but their study in America and Europe has received its greatest impetus from the development of the technique of microtome, polished, and thin section preparation. These methods of study have given new conceptions of the deposition and constitution of coals and to some extent of the process of coalification.

The difficulty of the technique and the time required in the preparation of the coals by these methods are, perhaps, obstacles to their general utility.

Students have used solvents from time to time to resolve the coal into a humic solution and an insoluble residue. White and Thiessen[1] have very ably summarized these methods and the results obtained.

The writer has for more than a year used the following schedule in studying coals from thirteen horizons in the Illinois coal basin.

PROCEDURE

The coal to undergo treatment is broken to lumps of twenty millimeters or less and covered with a modified Schultze's solution consisting of one part saturated potassium chlorate solution to four parts concentrated nitric acid. The Illinois coals usually require three or four days for complete oxidation although outcrop or weathered samples may be sufficiently disintegrated after eight or ten hours in the solution. The insoluble materials have been left in the solution for a period of two weeks or more without injury.

After oxidation is complete the acid-chlorate solution is decanted off and the macerated material is washed two or three times in water. A twenty-five per cent solution of ammonium hydroxide is then added to dissolve out the oxidized material. The usual procedure is to let

* Published by permission of the Chief, Illinois State Geological Survey.

[1] White, David, and Thiessen, Rheinhardt, The Origin of Coal, U. S. Bureau of Mines, Bull. 38, p. 216, 1914.

this basic solution remain on the material for five or six hours and add water to increase the volume twenty-five or thirty times. The residue is allowed to settle and the liquid is decanted off. It is then washed several times in a liter or more of water.

At this point a little of the residual material may be observed under the microscope. A watch glass containing a small amount of the material in water has been found convenient for this purpose. If the plant debris is curled or can not be easily separated it should be soaked in a solution of lacto-phenol for 24 to 48 hours. This solution is made by mixing 20 parts of phenol, 20 parts of lactic acid, 40 parts of glycerine, and 20 parts of water. It softens the material and restores it to its original shape. The lacto-phenol is washed out thoroughly with water and the material is placed in absolute alcohol where it may be left indefinitely. Plant fragments left in water for a month or two disintegrated so as to become unrecognizable.

The plant fragments in the alcoholic solution may be conveniently studied with a binocular microscope. In making permanent slides the desirable fragments are located with the microscope and removed with fine tweezers or a pipette. Several pieces are placed on a dry microslide and allowed to stand until the alcohol entirely evaporates. Two or three drops of Canada balsam that has been slightly thinned with xylol is put on and the cover glass placed in position. Two or three weeks are required for the balsam to dry as it is not desirable to heat it during the process of mounting.

The material may be stained at the alcohol stage with fast green, saffranin, or phloxine stain but it is perhaps not desirable except when it is necessary to accentuate the cell structure of epidermis. Spore cases and other structures become dark if stained. If the staining is too deep it may be lightened by placing the material for a few seconds into alcohol that has been acidulated with two or three drops of hydrochloric acid. As these stains are usually made up in alcoholic solution the material may be transferred directly to the slide for drying before mounting.

Significance and Character of the Residue

The plant fragments obtained by this method of treatment promise to be of significance geologically as horizon markers. A survey study has been made of residues obtained from the Babylon (Pottsville) coal of Fulton County, Illinois, through the most persistent coal beds to the No. 8 (McLeansboro) coal of Macoupin County. In sampling, an attempt was made to secure quantities representative of the entire seam.

Detailed study has been limited to the Pope Creek and No. 5 coal horizons of Fulton County and, although this investigation is not completed, there appears to be a characteristic plant assemblage for each horizon.

Some of the most delicate anatomical structures, such as pitted vessels (Fig. 1, Plate II) and transverse fragments of the woody parts of vascular plants (Fig. 6, Plate II) have survived coalification. Occasional organizations show characteristics that may prove of value in describing species.

Assemblages

The outstanding characteristic of the Pope Creek coal is the presence of splinters made up of the vessels of woody plants. Fragments 20 millimeters in length are common. Epidermis and cuticle form more than one fourth of the residue but are relatively inconspicuous in comparison to the darker vessels noted above. The coal also contains both microspore and megaspore exines that have not been observed in higher horizons.

The No. 5 seam is characterized by a preponderance of epidermal tissue of many kinds. Megaspores and microspores are abundant but fragments of woody material are less prominent than in the Pope Creek coal.

In all coals studied cryptocrystalline quartz constitutes a small but conspicuous part of the residue. The mineral may fill the lumen of the cell or may occur free in minute grains that often have the form of the cells from which they have become separated. The lack of distortion in the cell walls (Fig. 5, Plate II) suggests that the mineral was present soon after deposition. Much of the ash in these coals may have resulted from a partial silicification of the plants in the early stages of coalification.

Epidermis and Cuticle

(Plate I)

Two types of cell arrangement are reflected by the cuticles shown in figure 1 and figure 5.

An epidermal layer that resembles that of modern grasses in its structure is shown in figure 2.

Figure 3 is of a fragment of epidermis which bears stomata in definite rows. Raised and thickened guard cells surround the openings.

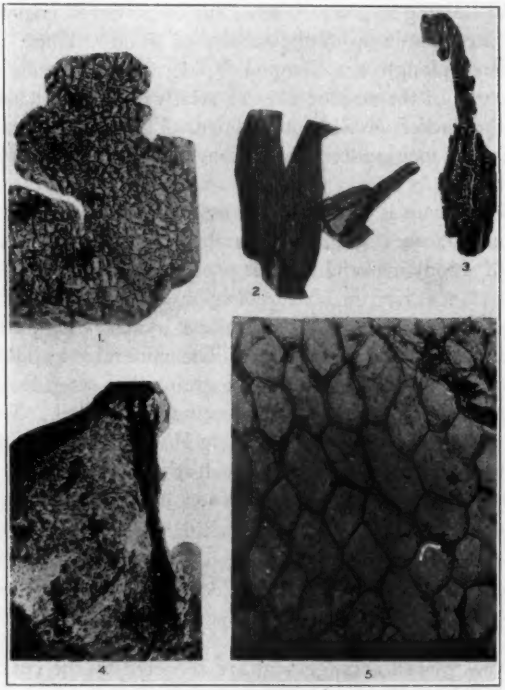
Figure 4 shows the epidermis of a leaf attached to the midrib. A few stomata and glands are present.

Woody Structures

(Plate II)

The organization of woody structures in the identification of living and fossil plants is of great importance. That some such value may obtain from residues won from coal appears probable and it is with this in mind that this material is presented for criticism.

The vessels in the fragment shown in figure 1 are of interest because of the uniseriate bordered pits. Uniseriate pitting is characteristic of the living Abietineae and the similarity of this fossil speci-



EXPLANATION OF PLATE I.

Fig. 1. Cuticle from Pope Creek Coal.

Fig. 2. Epidermis from No. 5 Coal.

Fig. 3. Epidermis from Pope Creek Coal. Stomata with thick guard cells appear in rows.

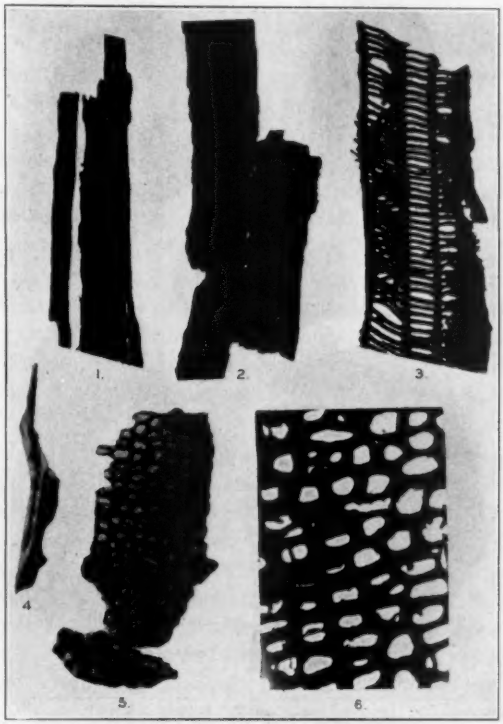
Fig. 4. Leaf epidermis attached to midrib. Small glands and stomata are present.

Fig. 5. Cuticle from No. 6 Coal.

men to corresponding sections of Cedrus[2] is striking. Multiseriate pitting of a vessel is illustrated by a section (Fig. 2) from another coal horizon.

Figure 3 and figure 4 illustrate scalariform vessels from No. 5 and the Pope Creek coals, respectively.

Figure 5 is a transverse section of secondary wood in which cryptocrystalline quartz has replaced the original cytoplasm. Figure 6 is a more highly enlarged section of the same wood.



EXPLANATION OF PLATE II.

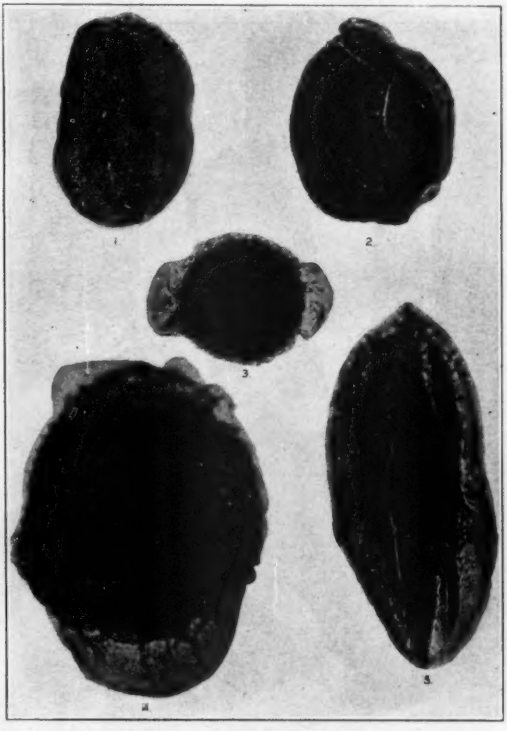
FIG. 1. Vessels from Pope Creek coal showing uniseriate pitting.
FIG. 2. Multiseriate pitting in vessels from No. 5 coal.
FIG. 3. Scalariform vessels from Pope Creek coal.
FIG. 4. Scalariform vessels from No. 5 coal.
FIG. 5. Transverse section of secondary wood (No. 5 coal) with quartz filling lumens of cell.
FIG. 6. More highly magnified portion of Figure 5.

[2] Jeffrey, E. C., The Anatomy of Woody Plants, p. 74, University of Chicago Press.

Spores

(Plate III)

Some spore types from No. 5 coal are illustrated by figures 1 to 5. Those bearing wings (Figs. 3 and 4) indicate that the spore was no longer dependent upon water for transportation but was carried by the wind in the manner of the winged pollens of modern conifers.



EXPLANATION OF PLATE III.

Figs. 1, 2 and 5 are unwinged spores from No. 5 coal.
Figs. 3 and 4 are winged spores from No. 5 coal.

PRELIMINARY MICROSCOPIC INVESTIGATION OF ILLINOIS COAL

BY

CLAYTON G. BALL

State Geological Survey, Urbana.

In recent years a number of investigators have thoroughly studied the microscopic constitution of coal and have definitely established its vegetable composition. At first this work was general in scope, the investigations being concerned mainly with the original nature and succeeding modification of the coal material. Lately, however, Slater[1] in England, and Thiessen[2] in America have studied in minute detail specific coal seams, endeavoring to establish some sort of significant criteria for purposes of correlation.

Although pictures of thin sections cut from Illinois coals have been published in some of the literature on this subject, there has been no attempt made to determine the presence of any microscopic properties characteristic of coals of this State. A preliminary survey of this sort has been undertaken by the author under the auspices of the Illinois State Geological Survey.

A modification of the technique employed by Thiessen[3] is used in the preparation of thin sections of Illinois coal. Blocks are cut in the mine so as to make a complete column from bottom to top of the coal seam. Each block is carefully labeled and its position and orientation in the column indicated. In the laboratory the blocks are usually strengthened by immersing them in paraffin for from 24 to 48 hours at 60° Centigrade. More friable coals may be impregnated under vacuum with liquid bakelite and then baked for 12 hours at 105° Centigrade, after which they are quite hard and coherent under further treatment. Square chips about ¾ inch wide and ¼ inch thick are cut at right angles to the bedding. One face of the chip is ground flat on glass plates with successively finer carborundum powders and then polished on "selvyt" cloth using a paste of very fine slaked lime and

[1] Slater, L., Evans, M. M., and Eddy, G. E., The Significance of Spores in the Correlation of Coal Seams, Part I, Department of Scientific and Industrial Research, Fuel Research, Physical and Chemical Survey of the National Coal Resources, No. 17, 1930.

[2] Personal Communication, Dec., 1930.

[3] White, David, and Thiessen, Reinhardt, The Origin of Coal, U. S. Bureau of Mines, Bull. 38, pp. 213-216, 1914.

water. After drying, the block is cemented on an object slide with Kollolith, a German preparation similar to Canada balsam. The chip is then ground down to transparency, first on a revolving lap, then on glass plates with the fine carborundum powders, and finally on a carefully selected Belgian hone. The final steps in the grinding demand extreme patience and care as coal at best is brittle and friable and a thin section may easily be torn and spoiled. At each step in the process of preparing a section, the number of the chip and its orientation is scratched on the coal or on the slide, and when completed a label indicates the position and uppermost side of the coal chip in the bed. After the final grinding the thin section is dehydrated with absolute alcohol and a cover glass is cemented on with Canada balsam or Kollolith.

The microscope reveals that coal is exceedingly variable in composition. Except for occasional mineral grains and mineral partings, the coal is made up exclusively of plant remains. Most of the organic material is seen to consist of a complex ground mass in which are embedded larger plant fragments. With higher magnification the ground mass resolves into disassociated fragments of wood and bark, particles of resinous matter, cuticle, and undifferentiated debris. This "attritus," as Thiessen[4] has named it, is composed of two sorts of material. It may be transparent under high magnification, or it may be opaque. The latter type has not been found in Illinois coals as yet.

Embedded in the ground mass are plant entities, spore-exines and resins being the most conspicuous. The resin particles are almost always spherical or oval in shape and were evidently strong enough to resist crushing in the processes of coalification. Dark coloured resins occur as isolated bodies or grouped in broad bands, whereas light coloured resins are distributed throughout the finely disseminated attritus or are retained in their original cellular positions in the wood.

Megaspore- and microspore-exines are prominent, the latter being one of the most common constituents in the attritus. Occasionally they are found in distorted groups and probably represent crushed sporangia. Remnants of the sporangia wall are sometimes preserved. Although the original shape of the spores was round or elongate, the exines have become flattened and disc-shaped during the process of compacting. Wing-like appendages, tufted ramenta, and other ornamentation can often be recognized on both the megaspore- and microspore-exines. Strips of cuticle are easily recognized because of their bright yellow color and distinctive form. They usually appear on one or both sides of crushed tissue, the inner surface of the cuticles being

[4] Thiessen, Reinhardt, Structure in Paleozoic Bituminous Coals, U. S. Bureau of Mines, Bull. 117, p. 25, 1920.

sharply serrate, while the entire strip may appear broken wherever stomates are encountered.

Especially noticeable in the macroscopic as well as in the microscopic study of coal are the glanz or bright bands. In thin sections these bands are long, lenticular, and of varying thicknesses, with a homogeneous appearance that marks them as individual plant structures. Often definite cell-structure is well preserved, indicating that they are crushed woody parts of the trees and shrubs that grew on the peat bog. Where cell structure is lacking it is more difficult to visualize the woody derivation of these bands. Some sort of replacement by a "fundamental jelly" may be indicated. These bright bands derived from wood are called "anthraxylon" by Thiessen.[5]

Fusain or "mineral charcoal" is a common constituent found in thin sections of coal. This is an opaque material observed in small, lenticular patches and in thin, broad partings. It retains an uncrushed, open, cellular structure, the cells sometimes being filled with secondary calcite or pyrite. By some authorities fusain is supposed to have originated from bacterial decay, although Jeffrey suggests that it represents wood charred by forest fires.[6]

The chief inorganic constituents of coal are pyrite and calcite or gypsum. Pyrite, quartz, and other small indeterminable grains are scattered irregularly through the bedding and make up a large part of the original ash of coal. Other grains of pyrite are locally abundant, sometimes in the heterogeneous ground mass and again in the anthraxylon. These are roughly spherical in shape and may have minute arms radiating out into the surrounding coal. This type of impurity was probably formed at some time after the deposition of the peat.

After establishing the plant origin of coal and identifying so far as possible the organic constituents, it has been the aim of investigators to set up some means of correlation between widely separated parts of coal horizons. Some sort of plant "index" fossil would serve this purpose admirably, but no recognizable plant identities have as yet been found in Illinois coals which do not have too wide a vertical range to be useful. Correlation may possibly be attempted with spore-exines, but a thorough and comprehensive classification must first be made. Identifying ornamentations on the exines are so modified in appearance because of the various planes in which they are cut that classification of this sort must be restricted to a relatively few groups.

[5] Thiessen, Reinhardt, Structure in Paleozoic Bituminous Coals, U. S. Bureau of Mines, Bull. 117, p. 24, 1920.

[6] Jeffrey, E. C., Origin and Organization of Coal, Memoirs Amer. Acad. Arts and Sci., Vol. 15, No. 1, 1924.

Thiessen[7] has developed a new avenue of approach to this problem. It seems probable that a complete section of a coal bed in any one place will exhibit the same gradation and vertical changes in its composition as other sections throughout the coal horizon. Therefore if a uniform profile can be set up for one coal seam and if that profile is different from those found for other coal seams, a dependable standard of correlation may be established. The proof of a method of this sort necessitates careful and detailed work. In the pursuit of such a study, other uses for coal microscopy will be earnestly sought for. Inherent characteristics of the coal as revealed in thin section may be found to have valuable applications in the industrial and commercial uses of coal.

[7] Personal Communication, Dec., 1930.

THE QUESTION OF A PENNSYLVANIAN OVERLAP IN THE ROCK ISLAND REGION*

BY

H. R. WANLESS

University of Illinois and State Geological Survey, Urbana

SUMMARY OF PREVIOUS INVESTIGATIONS

In 1870 Worthen described the section of Coal Measures strata exposed in Fulton County, Illinois, in the valley of Spoon River as "the most complete and typical in the State,"[1] and designated the coal beds there exposed as Nos. 1 to 7. The typical exposure of No. 1 coal was stated to be in the west bank of Spoon River in the vicinity of Seville. Subsequently the coal of Rock Island and Mercer counties was correlated with this bed[2] and the term Rock Isand (No. 1) coal has been used in numerous reports. In 1906-1908 Dr. David White made paleobotanical studies of the Illinois Coal Measures to determine the approximate correlatives in Illinois of the various divisions of the Pennsylvanian in the Appalachian province.[3] He stated that the beds below coal No. 2 of the Illinois strata were approximately equivalent to the Pottsville formation in the Appalachian province, and the fossil floras of the Rock Island region were identified as the equivalents of the floras from upper Pottsville strata in Ohio and Pennsylvania. The strata between and including coals Nos. 2 and 6 and possibly No. 7 in Illinois belong in the Allegheny formation. Because the exact upper boundary of the Allegheny in Illinois could not be determined, the local name of Carbondale was applied to the beds approximately equivalent to the Allegheny, and the name McLeansboro was given to the higher beds approximately equivalent to the Conemaugh. The boundary between the Carbondale and McLeansboro formations was placed at the top of the No. 6 coal.

In the course of detailed studies in the Rock Island region in connection with the geologic mapping of the Edgington and Milan

* Published with the permission of the Chief, Illinois State Geological Survey.

[1] Worthen, A. H., Geology of Fulton County, Geol. Survey of Illinois, Vol. 4, Geology and Paleontology, pp. 92-94, 1870.

[2] Worthen, A. H., and Shaw, James, Geology of Rock Island County, Geol. Survey of Illinois, Vol. 5, Geology and Paleontology, pp. 221, 229-232, 1873.

[3] White, David, Report of the field work in the coal districts of the state, Illinois State Geol. Survey Bull. 4 (Yearbook for 1906), pp. 201-203, 1907.
White, David, Report on field work done in 1907, Illinois State Geol. Survey Bull. 8 (Yearbook for 1907) pp. 262-272, 1908.
White, David, Paleobotanical work in Illinois in 1908, Illinois State Geol. Survey Bull. 14, (Yearbook for 1908), pp. 293-295, 1910.

quadrangles and the collection of data on the coal resources of district III (Western Illinois), new evidence was discovered which threw doubt upon the correlation of Pennsylvanian strata in the Rock Island region. The fusulinid *Fusulina girtyi* (then known as *Girtyina ventricosa*) was discovered to be abundantly distributed in the limestone cap rock of coal No. 6, and it was thought to be a reliable guide to that horizon. It was also believed that no fusulinids were present below the McLeansboro or upper Carbondale beds. The discovery of fusulinids in abundance in a limestone exposed near Andalusia, Rock Island County and in the limestone cap rock of coal mined at Carbon Cliff and Coal Valley, Rock Island County, Matherville, Sherrard and Cable in northern Mercer County, and near Briar Bluff and Geneseo, Henry County, suggested that the strata in this region were much younger than had been thought.[4] Further field work in the western part of the State convinced Dr. Culver that an abundance of fusulinids was not a reliable guide to the limestone above coal No. 6, and that they occur much lower in the section than the upper Carbondale. However, he discovered that the sequence of beds—"slaty shale, argillaceous limestone, sandy shale, and sandstone"—associated with the "Rock Island" coal of Rock Island and northern Mercer counties was closely similar to the succession of beds associated with the coal at Sheffield, Bureau County, and Kewanee, Henry County, which was correlated with the No. 6 coal of Fulton County.[5]

Another criterion which was used in establishing this revised correlation was the presence of a clay band in the coal of the Rock Island region which was believed to be the same as the "blue band," a widely distributed clay parting in No. 6 coal.

As a result of the revised correlation of the coal in the Rock Island region, an overlap of strata of later Carbondale and early McLeansboro age toward the northwest margin of the Eastern Interior coal basin was postulated. No. 6 coal and associated strata were recognized very near the western boundary of the coal basin farther south in Adams County and in Randolph County. These observations led to the theory of the gradual extension of the Pennsylvanian basin of sedimentation during

[4] Culver, H. E., Note on the occurrence of Fusulina in the Pennsylvanian rocks of Illinois, Trans. Ill. State Acad. Sci. for 1922, Vol. 15, pp. 422-425, 1922.
Savage, T. E., and Udden, J. A., Geology and mineral resources of the Edgington and Milan quadrangles, Illinois State Geol. Survey Bull. 38C, pp. 3, 37, 38, 44-49, 1922.
Savage, T. E., Marine invertebrate fossils as horizon markers in the Pennsylvanian rocks of Illinois, Jour. Geol. Vol. 32, p. 581, 1924.
Savage, T. E., Significant breaks and overlaps in the Pennsylvanian rocks of Illinois, Amer. Jour. Sci., Vol. 14, p, 314, 1927.

[5] Culver, H. E., Pennsylvanian correlation in northwestern Illinois, Bull. Geol. Soc. Amer., Vol. 35, pp. 321-328, 1924.
Culver, H. E., Coal resources of District III (Western Illinois), Illinois State Geol. Survey Coop. Mining Ser. Bull. 29, pp. 16-17, 19-20, 99-104, 1925.
Culver, H. E., Present status of correlation of Illinois coals, Illinois State Geol. Survey Rept. Inv. No. 14, 1927.

the Pottsville and Carbondale to a maximum size attained during the latest Carbondale and early McLeansboro stages.[6] Recently this overlap has been interpreted as indicating the disappearance of the Pottsvilla strata near the northwest margin of the Eastern Interior coal basin in Illinois and southeastern Iowa.[7]

Field work in the Alexis quadrangle in 1925 and 1926 demonstrated that the "Rock Island" coal of southern Mercer County was actually equivalent to No. 1 coal of Fulton County and stratigraphically 80-125 feet below the top of the Pottsville formation.[8] The limestone cap rock of the coal in that area contains an abundance of small fusulinids which have been found to represent two unnamed species both of which are different from *Fusulina girtyi*.[9]

Recent Investigations

During the field seasons of 1929 and 1930, the writer, assisted by Mr. Sidney E. Ekblaw, has traced the Pennsylvanian strata from Worthen's type section in Fulton County north through Knox, Warren, and Mercer counties to the Rock Island region, eastward along the northern border of the coal basin across Rock Island, Henry, and Bureau counties, and southward along the Illinois River valley through Bureau, Marshall, and Peoria counties to Fulton County. The general stratigraphic section worked out in this region extends from the base of the Pennsylvanian to the horizon of coal No. 8, about 150 feet above the base of the McLeansboro formation.[10] All of the exposures cited by Savage and Culver to establish the overlap in the Rock Island region were revisited.

This study has demonstrated that there is no overlap of No. 6 coal toward the northwest border of the Eastern Interior coal basin. The Pottsville strata were found to be actually thicker in Rock Island County than in Mercer, Knox, Warren, and Fulton counties to the south, and the basal strata along the northern border of the coal basin are as old as, if not older than, the basal strata 80 to 100 miles to the southeast in Fulton County. The entire Carbondale formation is also

[6] Culver, H. E., Present status of correlation of Illinois coals, Illinois State Geol. Survey, Rept. Inv. No. 14, pp. 10-11, 1927.
Savage, T. E., Significant breaks and overlaps in the Pennsylvanian rocks of Illinois, Amer. Jour. Sci., Vol. 14, pp. 313-315, 1927.
Savage, T. E., Sedimentary cycles in the Pennsylvanian strata, Amer. Jour. Sci., Vol. 20, p. 130, 1930.

[7] Levorsen, A. J., Pennsylvanian overlap in the United States, Bull. Amer. Assoc. Petroleum Geol., Vol. 15, p. 118, figs. 8, 17, 1931.

[8] Wanless, H. R., Geology and mineral resources of the Alexis quadrangle. Illinois State Geol. Survey, Bull. 57, pp. 63-64, 1929.

[9] The identification was made by Mr. L. G. Henbest.

[10] Wanless, H. R., Pennsylvanian cycles in western Illinois, Illinois State Geol. Survey, Bull. 60, pp. 179-193, 1931.
Wanless, H. R., Pennsylvanian Section of western Illinois, Bull. Geol. Soc. Amer. Vol. 42, (In press).

well developed to the limit of its outcrops and shows no indication of appreciable thinning to the northwest.

Stratigraphic Evidence

The principal stratigraphic evidence that there is no overlap of No. 6 coal in the Rock Island region is the recognition here of several "key beds" of the typical Fulton County strata which have been traced northward to the northern border of the Illinois coal basin. The following key beds have proved most useful:

1. **Coal No. 6 and its limestone cap rock.**
2. **Coal No. 5 and its overlying carbonaceous shale.**
3. **Limestone and conglomerate over coal No. 4.**
4. **Coal No. 2 and its associated strata.**
5. **Seahorne limestone (20-40 feet below Coal No. 2).**
6. **Coal No. 1 and its overlying limestone and shale.**

(1) *Coal No. 6.* Herrin (No. 6) coal and its limestone cap rock have been traced from Cuba (T. 6 N., R. 3 E.) to Middle Grove (T. 8 N., R. 3 E.), Fulton County; Wataga (T. 12 N., R. 2 E.), Knox County; Galva (T. 14 N., R. 4 E.) and Kewanee (T 15 N., R. 5 E.), Henry County; and Sheffield (T. 16 N., R. 7 E.), Bureau County. The coal is 4 feet 6 inches thick at Cuba, 3 feet 6 inches to 4 feet thick at Middle Grove, 3 feet 2 inches to 4 feet thick at Wataga, 3 feet thick near Galva, 4 feet 2 inches thick near Kewanee and 3 feet 9 inches thick at Sheffield. In all of this area the limestone cap rock is less than 1½ feet thick and it is so discontinuous that it is absent from about half of the exposures studied along its outcrop line.

(2) *Coal No. 5.* The Springfield (No. 5) coal has been traced from Cuba (T. 6 N., R. 3 E.) north to Fairview (T. 8 N., R. 3 E.), Fulton County; Rapatee (T. 9 N., R. 3 E.), near Abingdon (T. 9 N., R. 1 E.), Galesburg (T. 11 N., R. 1 E.) and Soperville (T. 12 N., R. 1 E.), Knox County. Near Rio (T. 13 N., R. 1 E.) Knox County, the underclay of coal No. 5 is exposed without an overlying coal bed, and east of Cambridge (T. 15 N., R. 3 E.), Henry County, the seam is also absent, although its horizon is exposed. Throughout this distance the Springfield coal thins rather regularly and the limestone cap rock changes from a persistent bed of limestone 1 to 2 feet thick to discontinuous masses or nodules of limestone and at the northern edge of the basin it is entirely absent. The thinning of the coal is revealed by these measurements: 5 feet near Cuba, 4 feet near Fairview, 3½ feet at Rapatee, 3½-4 feet near Abingdon, 2½ feet south of Galesburg, 1½ feet at Soperville and absent at Cambridge.

(3) *Coal No. 4.*[11] No. 4 coal lies only 5-15 feet below No. 5 and it has been found at all of the places mentioned in connection with that coal. It is commonly a thin bed 1-4 inches thick throughout most of this region, but it thickens at various places to a bed 3-6 feet thick, as near Cuba and Fairview, Fulton County, and near Soperville, Knox County. The roof beds of this coal are a black shale with large subspherical black calcareous concretions overlain by the Hanover limestone. The black concretions are very easily recognized in the field and have been found from the vicinity of Alton north to Cambridge and east along the northern border of the field to Mazon Creek, near Morris, Illinois.[12] The Hanover limestone is best developed southward from Fulton County. It is discontinuous in Fulton County, but reappears northward and eastward in Knox, Peoria, Henry, and LaSalle counties with a very easily recognized lithologic character. In the southern part of western Illinois it is a thick, rather pure, light gray limestone, but in the northern area it is commonly a conglomeratic or glauconitic limestone.

(4) *Coal No. 2.* No. 2 coal has been traced northward from Seville (T. 6 N., R. 1 E.) to Babylon (T. 7 N., R. 1 E.), Fulton County; near Abingdon (T. 9 N., R. 1 E), Knox County; Cedar Creek east of Monmouth (T. 11 N., R. 2 W.), Warren County; Viola (T. 14 N., R. 2 W.), Mercer County; west of Geneseo (T. 17 N., R. 2 E.) and Atkinson (T. 17 N., R. 4 E.), Henry County. An outlier of this seam has been discovered near Andalusia (T. 16 N., R. 3 W.), Rock Island County. No. 2 coal is very easily identified by the overlying sequence of gray shale, black shale, and several thin impure limestone beds interbedded with dark fossiliferous shale. The thickness of this coal varies from 1½ to 3 feet in northwestern Illinois.

(5) *Seahorne limestone.* The Seahorne limestone differs from most of the other persistent lower Pennsylvanian limestones in that it is not the cap rock of an important coal. A thin coal 1-3 inches thick occurs about 1 foot below it and it is commonly less than 2 feet below a somewhat thicker coal ½ to 2 feet thick (Wiley coal). The upper surface of this limestone is commonly very uneven with knobs projecting into the overlying clay. Its thickness is variable and in many places it passes into a discontinuous band of limestone concretions. Its color is light gray and it is somewhat purer than the other Pennsylvanian limestones in northwestern Illinois. Fossils are very abundant in some places, but elsewhere they are rare or absent. A rather large

[11] This number is used for convenience only as this seam is not the one to which the number "4" was originally applied by Worthen.

[12] The exposures of these concretions from LaSalle eastward have been discovered and correlated by Mr. H. B. Willman.

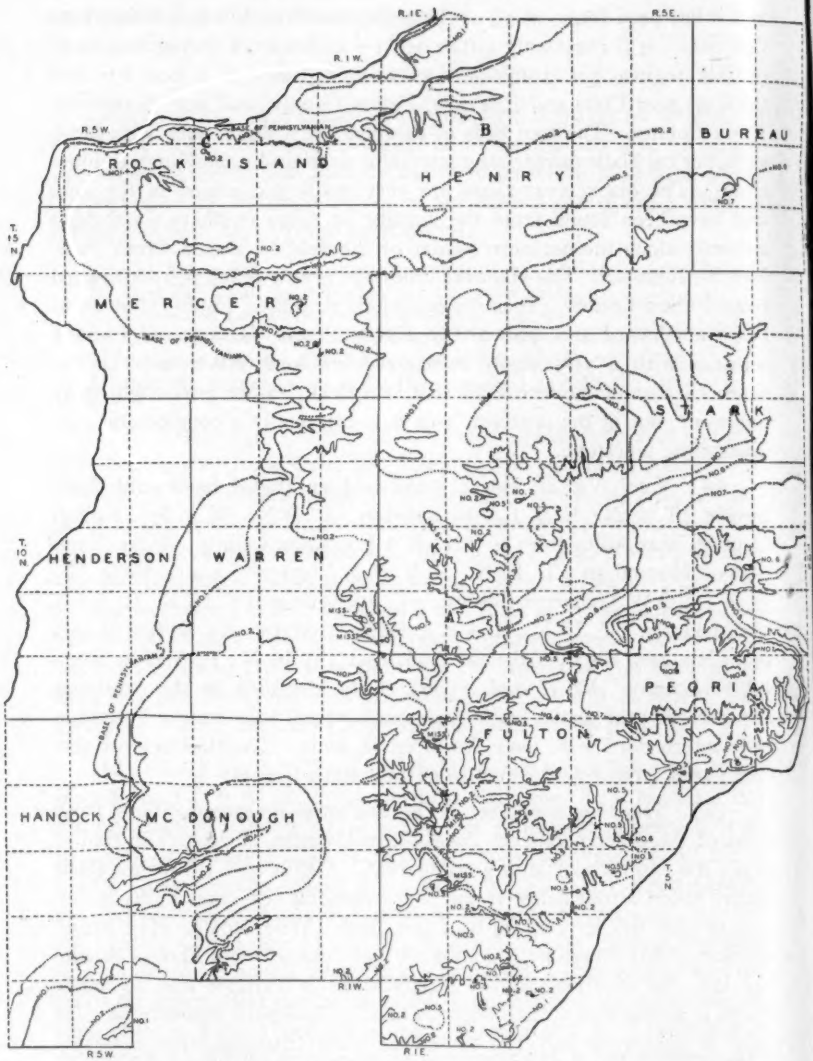


Fig. 1. Outline map of the northwestern part of the Illinois coal field showing the outcrop lines of the base of the Pennsylvanian and coals 1, 2, 5, 6, 7, and 8. Solid lines show definitely determined boundaries and dotted lines are used in areas heavily covered by drift where the outcrop is concealed and in areas which have received only reconnaissance study.

fusulinid is abundant in some outcrops. The Seahorne limestone is quite persistent through Fulton County but dies out northward in the vicinity of London Mills. It has not been found in Knox or Warren counties, although its exact horizon, between the thin coal below and the thicker one above, has been recognized throughout these counties. Farther north the Seahorne limestone reappears and has been recognized near Millersburg (T. 15 N., R. 4 W.), Mercer County; near Briar Bluff (T. 17 N., R. 1 E.) and west of Geneseo (T. 17 N., R. 2 E.), Henry County; and west of Andalusia (T. 17 N., R. 3 W. and T. 17 N., R. 4 W.), Rock Island County. Its characteristics in this northern district are similar to those in Fulton County where it is typically developed, and in all the places mentioned its stratigraphic relations with No. 2 coal above or No. 1 below are revealed. This is the limestone from which fusulinids were first reported near Andalusia.

(6) *Rock Island (No. 1) coal.* No. 1 coal differs from most of the coals of western Illinois in its great variability in thickness and altitude and in the character of the associated rocks. It varies from a soot streak to 5 or 6 feet in thickness and often varies 2 to 4 feet in thickness and 20 to 30 feet in altitude within a few hundred yards. The areas of thick coal are long fairly straight belts averaging ½ to 1½ miles in width. Within these belts the character of the coal and associated strata is fairly constant, but outside them there may not be a single characteristic of the coal and associated beds which will make its identification as coal No. 1 certain. The limestone cap rock reaches a maximum thickness of 15-30 feet in the narrow belts of thick coal, but is commonly somewhat thinner. It is a dark blue-gray limestone which is quite impure. The whole thickness of the limestone has about the same characteristics in the Fulton County area. In Warren, Mercer, Rock Island, and Henry counties the lower part of the limestone is a massive bed 1-2 feet thick, locally known as "cap rock," and the upper part consists of rather slabby and unevenly bedded very impure limestone, blue gray to chalky buff in color, which is locally known as the "blue rock." The upper part of the limestone is more shaly than the lower part and it grades up into a calcareous or siliceous shale. In places a bed of chert occurs at the top of the limestone sequence. The coal and its overlying limestone can be traced northward from its type outcrop at Seville (T. 6 N., R. 1 E.) to Babylon (T. 7 N., R. 1 E.), Fulton County; the vicinity of St. Augustine (T. 8 N., R. 1 W.), Monmouth (T. 11 N., R. 2 W.), and Alexis (T. 12 N., R. 2 W.), Warren County; Viola (T. 14 N., R. 2 W.), and Sherrard (T. 15 N., R. 1 W.), Mercer County; Coal Valley (T. 17 N., R. 1 W.), Rock Island County; and Briar Bluff (T. 17 N., R. 1 E.) and Cleveland (T. 18 N., R. 2 E.),

Henry County. Within this area the only important regional change in the character of the succession is the increasing amount of chert and siliceous shale near the northern border of the basin. The lower part of the limestone above the No. 1 coal contains a small fusulinid at a number of localities, especially near Seville, Fulton County, Viola,

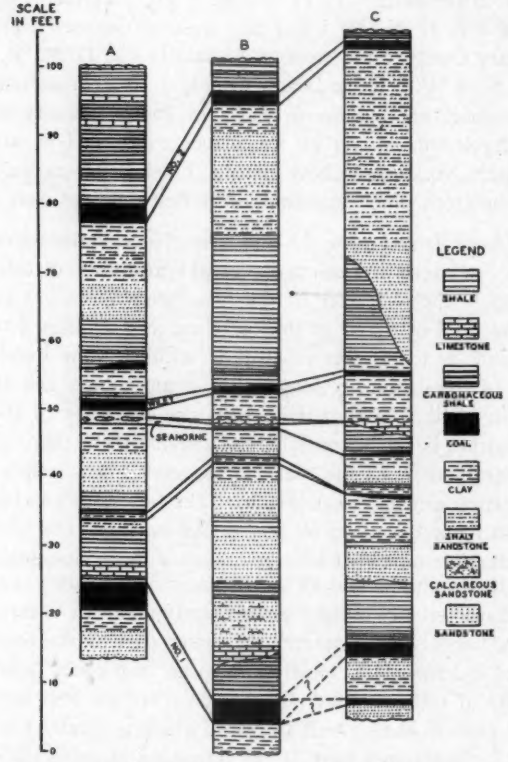


FIG. 2. Stratigraphic sections of Pottsville strata between coal No. 1 and coal No. 2 at (a) southern Knox County, east of Abingdon, (b) Mineral Creek, southwest of Geneseo, Henry County, and (c) 2 to 4 miles west of Andalusia, Rock Island County.

Millersburg and Mathersville, Mercer County, Coal Valley and Carbon Cliff, Rock Island County, and Briar Bluff, Cleveland and Geneseo, Henry County. These fusulinids in Mercer, Rock Island and Henry County outcrops were formerly believed to identify this limestone as the cap rock of coal No. 6.

Figure 1 shows the outcrop lines of the base of the Pennsylvanian and coals 1, 2, 5, 6, 7, and 8 in the northwestern part of the Illinois coal field. The data used in the preparation of this map include, in addition to the writer's own field notes, published reports, drill records and the notes of other members of the State Geological Survey.

In two localities near the northern border of the coal field the entire geologic section between the Rock Island (No. 1) coal and the No. 2 coal is exposed. These localities are (1) along Mineral Creek, southwest of Geneseo, Henry County and (2), 2 to 4 miles west of Andalusia, Rock Island County. The sections measured at these places, together with a section of the same interval near Abingdon in southern Knox County are shown in figure 2.

Summary of Stratigraphic Evidence

The strata exposed across Rock Island, Henry, and Bureau counties can all be placed in a standard stratigraphic section as it appears in the valley of Spoon River in Fulton County. The beds dip gently to the southeast and all strata outcropping between Rock Island and Sheffield occur in their normal position relative to the adjoining strata. Many details of this standard section were not known in 1921 when Culver and Savage interpreted the coal of the Rock Island region as the No. 6 bed. The geologic mapping of the Alexis, Monmouth, and Galesburg quadrangles south of the Rock Island region since 1925 and reconnaissance studies in unmapped areas have yielded much additional data on the stratigraphy of this area.

Lithologic Evidence

One of the reasons urged by Culver for the correlation of the Rock Island coal with No. 6 was that the sequence of beds associated with the "Rock Island" coal of Rock Island and northern Mercer counties was closely similar to the succession of beds associated with the coal at Sheffield and Kewanee. Many recent studies have shown that a coal bed is normally overlain by carbonaceous shale, limestone, and clay shale and underlain by underclay, shale, and sandstone.[18] The succession of beds from the sandstone below to the clay shale above, including the coal, record a cycle of sedimentation. The sort of sequence mentioned by Culver has been found in western Illinois

[18] Udden, J. A., Geology and mineral resources of the Peoria quadrangle, Illinois, U. S. Geol. Survey Bull. 506, pp. 47-50, 1912.
Stout, W., Coal formation clays of Ohio, Ohio Geol. Survey, Ser. 4, Bull. 26, pp. 533-568, 1923.
Weller, J. M., Cyclical sedimentation of the Pennsylvanian period and its significance, Jour. Geol. Vol. 38, pp. 97-135, 1930.

in association with coals 1, 2, 4, 5, 6, 7, 8, and 9, as well as several other seams which are not designated by number.

Another of the reasons urged for the correlation of the Rock Island and No. 6 coals is the presence of a clay parting in each coal. The clay parting known as the "blue band" in Coal No. 6 is persistent through the greater part of the Illinois coal field, but clay partings are also present in several other coal beds of western Illinois. The best examples are Coal No. 8 near Scottville, Macoupin County, Coal No. 7 at Sparland, Marshall County, Coal No. 4 near Bryant, Fulton County and Coal No. 1 at Viola, Mercer County and in many outcrops in Schuyler and southern Fulton counties. The clay band in coal No. 1 is quite variable in the northern part of Mercer County, ranging from zero to one foot within three miles. The presence of a clay band, therefore, cannot be used in the correlation of a coal bed unless it is in harmony with other stratigraphic evidence.

Paleontologic Evidence

The roof limestone of the Rock Island coal contains several fossils which are believed to be limited to horizons below the Herrin (No. 6) coal. These include *Productus nanus* Meek and Worthen and *Spirifer rocky-montana* (Marcou). The species *Chonetes mesolobus* Norwood and Pratten is represented by somewhat different varieties in the limestones over coals 1, 2, 5, and 6. The variety which occurs in the cap rock of the Rock Island coal is the same as that in the cap rock of the No. 1 coal in Fulton County, but it is quite distinct from the form which occurs in the cap limestone of the No. 6 coal.

The presence of fusulinids in the limestones of the Rock Island region has been considered important evidence that these limestones belonged above Coal No. 6. The limestone over coal No. 6 in Fulton County and in many other parts of Illinois contains *Fusulina girtyi* (Dunbar and Condra) in great abundance, but fusulinids have been found in practically every Pennsylvanian limestone in western Illinois. A careful study of the Fusulinidae of Nebraska has revealed the fact that many species of the family are valuable index fossils.[14] However, the discrimination of the species is based on twelve characters, of which only two are visible externally, the other ten being seen only in thin sections. The fusulinids in the cap rock of the Rock Island coal, as noted above, have been sectioned, and found to belong to two unnamed species, both of which are now known to be distinct from *Fusulina girtyi.*

[14] Dunbar, C. O., and Condra, G. E., The Fusulinidae of the Pennsylcanian system in Nebraska, Nebraska Geol. Survey Bull. 2, 2nd Ser., pp. 9-13, 49-50, 124-130, 1927.

THE MAGNETOMETER IN ILLINOIS*

BY

PERRY S. MCCLURE

State Geological Survey, Urbana

INTRODUCTION

The Illinois State Geological Survey began geophysical surveys with the magnetometer during the summer of 1929. The work was done by Mr. J. S. Young under the direction of Mr. G. F. Moulton. The surveys were continued in 1930 by the writer under the supervision of Dr. A. H. Bell. Most of the magnetometer surveys have been in areas where the geologic structure is well known, namely, Eastern Illinois, LaSalle area, Waterloo and Dupo oil fields, Sparta region, Ava-Campbell Hill gas field, Alto Pass quadrangle, Hardin County, and from Duquoin to Centralia. The entire survey covers an area of 3,240 square miles or approximately ninety townships. Some 1,620 magnetometer stations were established in these areas to measure the relative vertical magnetic intensity.

This report points out some of the principal anomalies of the earth's magnetic field in Illinois as revealed by measurement of the vertical component at numerous points and describes the effect of faults on the vertical magnetic intensity.

THE EARTH'S MAGNETIC FIELD

The construction and operation of magnetic instruments is based on the fact that the core of the earth acts as a huge magnet and the earth's crust is within the magnetic field of that magnet. The cause of the earth's magnetism is not completely understood, although it is generally conceded to be a deep seated magnetic force which acts as a spherical magnet.

A magnetic field is defined by lines of force which normally undergo a symmetrical variation in direction and intensity dependent upon their distance and direction from the poles of the magnet. The lines of force are vertical at the magnetic poles of the earth where its maximum intensity occurs. At the magnetic equator the magnetic field has a minimum intensity and the lines of force are horizontal, pointing toward the magnetic poles. The symmetry of the magnetic field between

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the magnetic poles and equator is distorted by local crowding together and thinning out of the lines of force. This distortion of the normal magnetic field is due to the fact that the source of the earth's magnetism is deep seated, and the lines of force which define its field must pass through the earth's crust.

This crust is composed of different kinds of rock of varying mineral content. Rocks that contain abundant magnetite have a high magnetic permeability and readily permit the passage of lines of force, producing areas of abnormally high magnetic intensity. Rocks containing little or no magnetite have a low magnetic permeability, retard the passage of lines of force, and so produce regions of abnormally low magnetic intensity. These regions of abnormally high and low magnetic intensity are called anomalies, because they are distortions of the earth's normal magnetic field.

A small bar magnet free to move about its center of gravity will align itself tangent to the lines of force of the earth's magnetic field. As it is impractical to suspend a magnet in this way, it is customary to determine the direction of the earth's field by means of two magnets, one turning about a vertical axis and another about a horizontal axis.

The declination, dip or inclination, horizontal intensity, and vertical intensity are known as the magnetic elements. The magnetic declination is the angle which the lines of force make with the geographic meridian. An eastward declination is positive and westward declination is negative. The vertical plane defined by the lines of force at any place is called the magnetic meridian. The dip or inclination is the angle which the lines of force make with the horizontal plane.

Magnetic Exploration

History

The magnetic method of exploration was first used to prospect for iron ore in Europe and the Lake Superior region of Michigan. The Dip or Miner's Compass[1] was used in Michigan to aid in locating iron deposits as early as 1869. Later the dial compass was devised by Brooks and used with the dip needle. These two instruments are particularly adapted to rapid exploration for large iron ore deposits and have been used extensively for such work. The dip needle[2] can be operated faster than any magnetic instrument in use, but its lack of sensitivity limits its field of usefulness.

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[1] Brooks, T. B., Iron Bearing Rocks, Geol. Survey of Michigan, Vol. 1, pt. 1, p. 210, 1869-1873.

[2] Stearn, Noel H., Practical Geomagnetic Exploration with the Hotchkiss Superdip, Amer. Inst. Mining and Metallurgical Engineers Tech. Pub. 370, p. 4. 1931.

Since 1869 a large variety of magnetic instruments have been devised and applied to magnetic prospecting, from the simple mining compass to the sensitive instruments used by the U. S. Coast and Geoditic Survey.

FIG. 1. Askania vertical type magnetometer.

MAGNETIC FIELD BALANCE

The Adolph Schmidt field balances[3] were developed to satisfy the need for instruments to rapidly measure the horizontal and vertical components of the earth's magnetic force in the field. It was also necessary that the instruments be more sensitive and reliable than such instruments as the dip needle. The Schmidt field balances are manufactured by Askania-Werke A. G. and are generally known as the Askania magnetometers. The vertical magnetometer has found a more general use, because the vertical component bears a simpler relation to the configuration of the buried magnetic masses than does the horizontal component. From measurements of the vertical and horizontal intensity the total magnetic intensity may be calculated.

[3] Heiland, C. A., Theory of Adolph Schmidt's Horizontal Field Balance, *in Geophysical Prospecting*, Amer. Inst. Mining and Metallurgical Engineers, p. 261, 1929.

Principles

The construction of the magnetometer is based on the fundamental law of magnetism that a magnet placed in a magnetic field will be acted upon by a force F = M x H where F is in dynes, M is the pole strength of the magnet, and H is the field intensity in gauss. In the vertical magnetometer, a magnetic system is balanced on a knife-edge perpendicular to the magnetic meridian. The center of gravity of the magnetic system is on the south polar side and below the pivot, so that the gravitational force due to the weight of the magnet system is balanced against the magnetic force which tends to make the system take up a position tangent to the lines of force of the earth's magnetic field. The position at which the magnet system comes to rest at a given place depends first, upon the position of its center of gravity with respect to the pivot, which is kept constant, and second, upon the strength of the earth's magnetic field which varies from place to place and from time to time. If the instrument is then moved to another place where the force of the earth's field is different, the magnet system will assume a new position. The change in position indicates a change in the magnetic force of the earth's field and the magnitude of the change in position is a relative index of the change in vertical intensity of the earth's magnetic field. The angular deflection of the magnetic system is directly proportional to the vertical intensity. The tilt or deflection of the balance system is measured by a telescope fitted with a scale and Gauss eyepiece.

Interpretation of Magnetic Anomalies

The interpretation of magnetic anomalies measured with the vertical magnetometer is a difficult and complex task. Differential permeability of the subsurface rocks causes distortions in the earth's magnetic field. This means that magnetic anomalies are definitely related to geologic features and therefore susceptible to geologic interpretation. The difficulty in determining the influence of geologic features complicates the correct interpretation of magnetic data. Stearn[4] gives the following list of geologic factors, which may influence the shape and magnitude of magnetic anomalies:

1. **Variations in mineral composition of the formations**
   a. **Due to primary distribution**
   b. **Due to secondary development**
2. **Variations in the attitude of the formations**

[4] **Stearn, Noel H., Application of geomagnetics to exploration, *in* Geophysical Prospecting, Amer. Inst. Mining and Metallurgical Engineers, p. 339. 1929.**

3. **Variations in the distribution of the formations**
   a. **Due to structural causes**
   b. **Due to erosion**
4. **Variations in the shape of the formations**
5. **Variations in topography**
   a. **Bedrock topography**
   b. **Topography of the overburden**
6. **Variations in the overburden**
   a. **In depth**
   b. **In mineral composition**

The correctness of any interpretation then, depends upon the number of variables known or partially known. It is sometimes possible to determine the influence of certain variables by making magnetic surveys across areas where the geology is well known. If the influence of certain variables is thus determined, the information may be useful in interpreting anomalies where geologic knowledge is meager.

There are many magnetic anomalies, regional in character, which are evidently caused by heterogeneities in the basement complex and the irregular surface of the basement complex. When it is definitely determined that there is nothing in the known geologic section to cause certain magnetic anomalies, then it seems reasonable to suspect the irregularities of the basement complex as causing the magnetic anomalies.

The shape of the magnetic field at any one point is the result of the effect of all the rocks through which the field passes. A deep-seated reaction may be masked or compensated by a reaction in the overlying rock, thereby complicating the interpretation of the measured anomalies. It is obvious then, that the correct interpretation of magnetic anomalies is dependent upon the available geologic data.

Magnetic Anomalies in Illinois

The "Map Showing Vertical Magnetic Anomalies in Illinois" (fig. 2) was made by using the magnetic intensity values obtained by the United States Coast and Geodetic Survey at all county seats in Illinois. The anomalies are determined by calculating the difference between the normal vertical intensity and the actual vertical intensity. If the actual intensity is greater than the normal intensity, there is a positive anomaly, and vice versa. The map gives only a rough idea of the distribution of the vertical magnetic intensity. The vertical intensity in Illinois has a variation of more than 2,000 gammas, a gamma being 1/100,000 of a gauss.

Positive magnetic anomalies occur in LaSalle, Kankakee, Henderson, Morgan, Edgar, St. Clair, Madison, Washington, Wayne, Saline, and Massac counties. Negative anomalies occur in Boone, Whiteside,

Marshall, Iroquois, Cass, Macon, Randolph, Union, and Pope counties. No attempt has been made to correlate these anomalies with the structural features of the State. Anomalies determined by stations forty to fifty miles apart are not outlined definitely enough to attempt

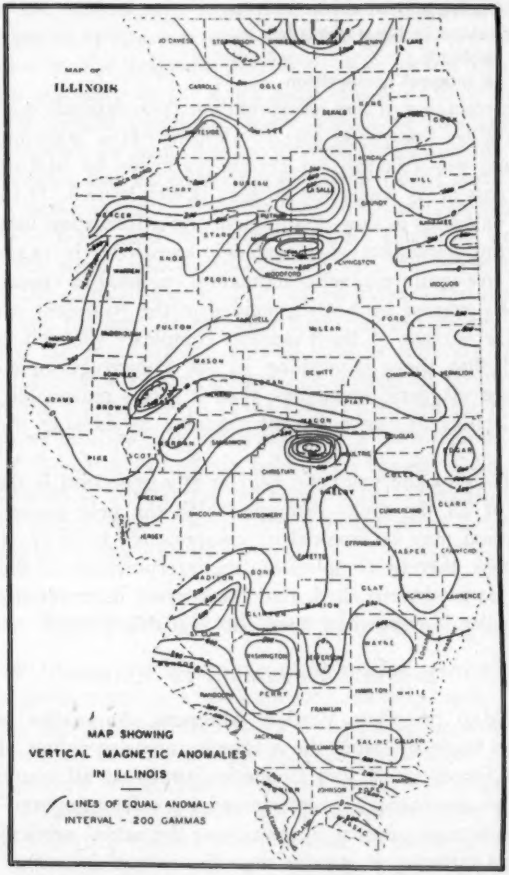
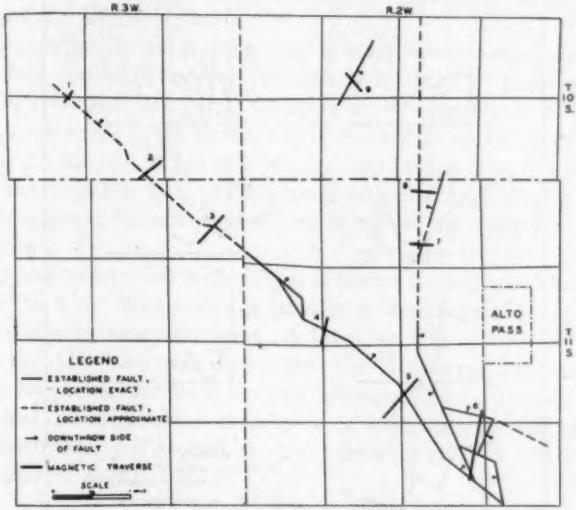


FIG. 2.

an interpretation. Reconnaissance surveys of such anomalies show that they are very irregular, although the trend of the magnetic highs and lows may remain the same.

The reconnaissance surveys in Illinois do not show a direct relationship between the vertical intensity and the structure. A magnetic

high does not necessarily indicate a structural high, nor a magnetic low a structural low. In eastern Illinois, near Paris, a magnetic high occurs above the Marshall-Sidell syncline. The highest intensity across the Waterloo anticline is on the east flank of the anticline. In the area between Duquoin and Centralia there are a series of magnetic highs and lows along the axis of the Duquoin anticline. In the Ava-Campbell Hill area magnetic features follow the structure in certain places and deviate from the structure in other parts of the area.



MAP SHOWING MAGNETIC TRAVERSES
IN ALTO PASS QUADRANGLE

FIG. 3.

The present status of the geophysical investigations in Illinois seems to indicate that the magnetic anomalies are caused by heterogeneities in the basement complex, irregular surface of the basement complex, or a combination of the two factors. This conclusion is based, first, on the variable relation between the magnetic features and the structural features, and second, on the fact that well-cuttings which have been examined do not contain sufficient magnetite to affect the magnetometer. In certain areas the glacial drift contains enough magnetite to affect the magnetometer, but it is improbable that it would cause the large anomalies known to be present in Illinois.

Tracing Faults With the Magnetometer

A series of magnetic traverses were run across certain known faults in Hardin and Union counties. The locations of traverses and a few faults are shown on the "Map Showing Magnetic Traverses in Alto Pass Quadrangle" (fig. 3). The faults were mapped several

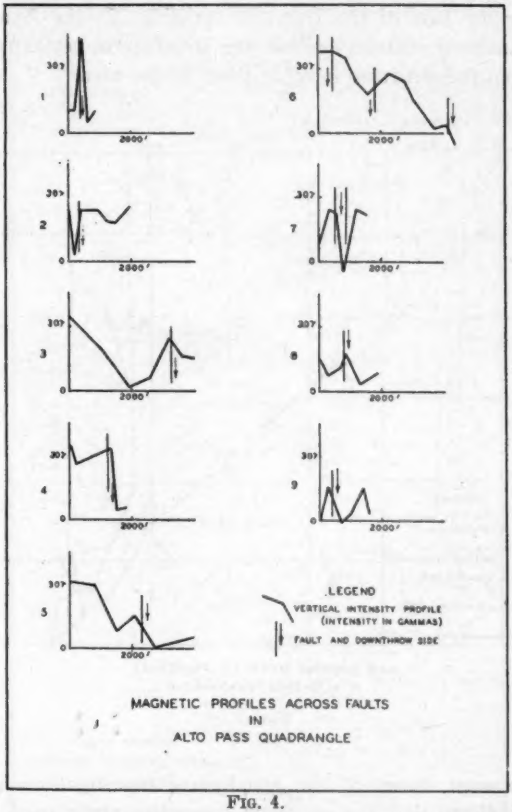

LEGEND
VERTICAL INTENSITY PROFILE (INTENSITY IN GAMMAS)
FAULT AND DOWNTHROW SIDE
MAGNETIC PROFILES ACROSS FAULTS IN ALTO PASS QUADRANGLE

Fig. 4.

years ago by Dr. Ekblaw.[5] Traverses 1 to 6 are across the major fault. This fault has a throw of 1,000 to 1,200 feet, bringing the Chester on the north in contact with the Devonian on the south. Traverses 7 to 9 are across faults affecting only the Chester strata with displacements of less than 200 feet.

Profiles of magnetic traverses across faults in the Alto Pass area are shown in figure 4. These profiles show that there is a magnetic

[5] Ekblaw, G. E., Post Chester, Pre-Pennsylvanian faulting in the Alto Pass Area, Illinois State Acad. Sci., Vol. 18, p. 379, 1925.

disturbance of 10 to 30 gammas within 200 feet of the mapped fault trace. As it was impossible to determine the exact position of the faults along the magnetic traverses, it is not certain just what relation exists between the fault trace and the magnetic disturbance. The available data seem to indicate an increase in intensity when approaching the fault on the upthrow side, then a sharp decrease in intensity after crossing the fault, followed by a gradual increase in intensity as the distance from the fault increases on the downthrow side. If this conclusion is true, the positions of some of the faults as mapped are slightly in error.

The profiles do not indicate any relation between the amount of throw along the fault and the variation in intensity. Profiles 1 to 6 show approximately the same variation in intensity as profiles 7 to 9, which are cross small faults. This absence in variation of intensity leads to the conclusion that the faulting in this area has not disturbed any magnetic beds. If magnetic beds had been displaced, the greatest magnetic variation would occur across the fault having the most throw.

The important point is that there is always a magnetic disturbance set up by a fault. This makes it possible to determine the location of faults in an area where outcrops are scare, such as tracing the major fault in the Alto Pass area west across the Mississippi flood plain.

The magnetometer then, has two principal uses in Illinois. First, in regional reconnaissance surveys it is quite possible to pick up structural trends, and second, in doing detailed work it will indicate the position of faults.

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LANDSLIDES NEAR PEORIA*

BY

GEORGE E. EKBLAW

State Geological Survey, Urbana

As most people associate landslides with mountainous, hilly, or rugged country, and as most of them also seem to be imbued with the misconception that Illinois is nothing but a flat, monotonous prairie, the statement that in this State landslides are very common generally occasions some surprise. Only those who through bitter experience have learned otherwise and those who have actually studied landslides appreciate fully the true situation. Despite the fact that landslides are common and do frequently present troublesome problems, they are not serious and possess no great potential dangers in Illinois. However, the prevalent false idea that they are non-existent engenders utter disregard, and this in turn does pave the way for preventable disasters.

The walls of the valley of Illinois River constitute an admirable locale for landslides, and in the vicinity of Peoria, where the Pennsylvanian system of rocks crops out and is overlain by glacial drift, landslides are numerous.

A particularly troublesome one occurs about two miles north of Sparland, about thirty miles north of Peoria. At this locality the material in the valley walls has been moving intermittently for a long while. The Chicago, Rock Island, and Pacific Railway, which runs along near the foot of the bluff, has been realigned several times at this place, and the total amount of its displacement is approximately twelve feet, as determined by comparing its present position with that of the original ballast. The telegraph poles have also been moved out of their original alignment.

When the State Bond Issue Highway Route No. 29 was constructed along the west side of Illinois Valley, it too crossed the landslide under discussion. The slab was not in position long until about two hundred feet of it was disturbed and cracked by the movement of the landslide and eventually it was disrupted, depressed, and moved out of line about five feet so that even when resurfaced it can be safely traversed at only slow speed.

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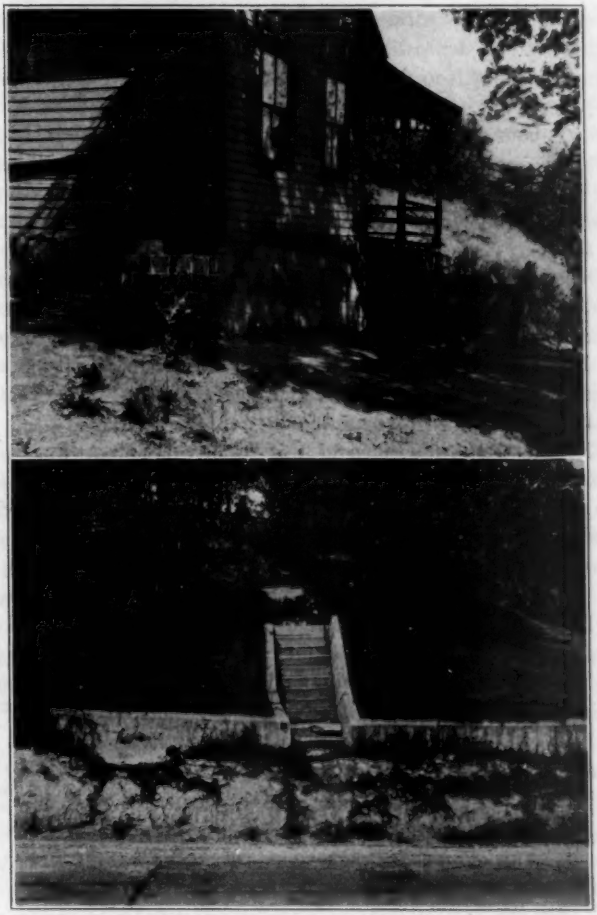

FIG. 1. *(Above)* **Foundation of a house disjointed and displaced as a result of landslide movement. Note the tilted steps and handrail and the distance the foundation has settled away from the porch at the right-hand corner.**

FIG. 2. *(Below)* **Steps broken and dislocated by landslide movement. The house that formerly stood here had to be moved away on account of the same landslide movement. Note also cracks in the wall and in the pavement in the foreground.**

A slightly depressed flat about 150 feet long and 50 feet wide developed in the valley-wall hardly ten feet higher than the pavement. Behind the depression there was exposed a sandstone layer about ten feet thick. The depression was wet and marshy, apparently fed by water seeping out from beneath the sandstone. Above the sandstone is another small flat in which there is minor seepage, and behind it there is a "bluff" about five feet high in which coaly shale is exposed. Above this there is another poorly developed flat, backed by a steep slope about thirty feet high in which silty or sandy shale is exposed. Above the silty shale is another poorly developed flattish zone, backed by a steep slope about forty feet high in which thinly bedded sandstone is exposed.

Depressions or flattened shelves alternating with slopes occur along the valley-wall for several hundred feet south of the location described. At one place particularly there is a long depression with a pressure ridge in front of it. The entire valley wall is a maze of depressions, low ridges, and slopes. Water stands in the depressions so that vegetation flourishes and contributes further to the maze.

The conditions described at this locality north of Sparland are almost duplicated at Bartonville, a few miles southwest of Peoria. There are practically no outcrops by which the strata can be determined, but there are two major horizons along which seepage and marshy depressions occur, and these are believed to be the same as those at Sparland. Everywhere the slope exhibits "eye-brow" landslips and the irregular alternation of arcuate ridges and crescentic depressions typical of landslide topography. Houses and other buildings on the slope have tilted and their foundations, the sidewalks, the pavement, and the retaining walls have been disrupted by the landslide movement (Fig. 2).

The strata at Sparland are correlated as follows:[1]

	Thickness in feet
Pennsylvanian system	
Gimlet cyclical formation	
Basal sandstone	40±
Sparland cyclical formation	
Farmington silty and sandy shale	30±
Black laminated shale	1±
Coal, No. 7	4±
Underclay, very plastic at top	0–6
Copperas Creek sandstone	10±
Brereton cyclical formation	
Shale	2±
Limestone	0–?
Black laminated shale	1±
Coal No. 6	0–3
Underclay	?
Sandstone	10±

[1] See H. R. Wanless' article, pp. 331-340.

The same strata are reported in the vicinity of Bartonville.[2]

The sandstones and coals are relatively pervious strata sandwiched between less pervious beds, so that the contacts between each sandstone and the underlying shale and between each coal and the underclay are potential horizons along which ground water may accumulate and seep out at favorable exposures. The contact of the glacial drift and bedrock is another potential horizon of seepage. The major seepages and consequent slumping both at Sparland and at Bartonville are believed to occur respectively at the base of the sandstone basal member of the Gimlet cyclical formation and at the base of coal No. 7. The disastrous sliding, which disrupts the pavement and other structures at both localities, is believed to occur in the combined shale and underclay zone between the Copperas Creek sandstone and the sandstone below coal No. 6, respectively the basal members of the Sparland and Brereton cyclical formations.

The ground water that seeps out at the contacts of the more porous above the less porous strata runs down over the surface and softens the clay and shale below it and also the talus already accumulated at the lower part of the slope. The softened, weathered clay and shale becomes plastic and may flow and slump if there is sufficient water. It has a low angle of repose and its equilibrium is easily disturbed. Thus the slips and slides are created. The overlying strata and talus may even slide bodily over the shale and underclay members when the latter are softened and lubricated by excess water.

The only real cure for these slides is drainage. However, it would be necessary to lay drains along each potential horizon of seepage and at the exact line and carry the water down the slope wherever there was a dip in the contact. The depressions would also have to be drained, and surface water would also have to be drained away. A system of drains sufficient for these purposes and the labor in determining the precise location for them as well as in laying them in talus material would be so expensive that the cost of drainage seems prohibitive. The most practical advice is to avoid such locations when considering construction of any kind.

[2] Udden, J. A., The geology and mineral resources of the Peoria quadrangle: U. S. Geol. Survey Bull. 506, pp. 31-44, Pl. I. 1912.

PALLIAL SINUSES OF *COMPOSITA ARGENTIA**

BY

J. MARVIN WELLER

State Geological Survey, Urbana.

The mantle or pallium which completely lines the internal surface of each valve of a brachiopod shell is composed, beyond the body of the animal, of two epithelial membranes which are firmly united by a uniform layer of cartilaginous connective tissue except along certain lines which are occupied by the pallial sinuses. These are tubes which open into the main body cavity or coelom and whose numerous ramifications extend to the border of the mantle. They are an important part of the circulatory system and in most brachiopods the genital organs extend into them.

In both mantles of a brachiopod the pallial sinuses issue in more or less diverging trunk lines which branch to a greater or lesser extent as the margin is approached. The patterns thus formed differ considerably in the various observed species and Thompson considers their disposition probably to be of at least superfamily value in classification.[1]

In most brachiopods the pallial sinuses have left no traces on the internal surfaces of the valves, but in others their pattern is preserved as a system of shallow grooves which on internal casts are shown by low rounded ridges. Although some species appear to retain traces of the pallial sinuses more commonly than others, specimens exhibiting these characters are quite rare and no traces of them have been observed among the abundant specimens of many very common species that have been collected.

Composita argentia (Shepard) is probably the most common Pennsylvanian fossil in America. It has been reported throughout a range extending from California to Maryland and from British Columbia to Brazil, and more than fifty descriptions and illustrations of this species have been published. In all these notices of the species there are only three references to the pallial sinuses. Herrick casually mentions "radiating lines on the dorsal valves . . . impressed upon the shell by

* Published by permission of the Chief, Illinois State Geological Survey.

[1] Thompson, J. A., Brachiopod morphology and genera (Recent and Tertiary), New Zealand Board of Science and Art, Manual No. 7, p. 11, 1927.

the viscera,"[2] but he neither describes nor figures these markings. On the other hand, internal casts showing traces of the pallial sinuses have been illustrated by Whitfield[3] and by Hall and Clarke[4] but not described. It is of considerable interest, therefore, that a small collection from the Vanport limestone in the NE. ¼ NW. ¼ sec. 25, T. 5 N., R. 18 W., Jackson County, Ohio,[5] contains a number of specimens in which the positions of these sinuses are clearly indicated. This collection was obtained from the dump of an old entry into the Clarion coal that was formerly worked in connection with the operations of the Diamond Brick Company. The Vanport limestone at this locality contains beds of massive, locally fossiliferious chert in which *Composita argentia* is

FIG. 1 and 2. **Pedicle and brachial views of an internal cast of *Composita argentia* showing pattern of pallial sinuses. Enlarged 3 diameters.**

especially common. The calcareous shells have been leached out and the fossils are preserved as external moulds which faithfully record delicate surface markings and as complete internal casts which may be easily obtained by simply breaking up the rock.

The accompanying figures are reproduced from enlarged photographs of the specimen which shows the pattern of the pallial sinuses in greatest detail. This specimen is slightly distorted as it probably was in life and consequently the sinuses are somewhat unsymmetrical.

The pallial sinuses appear to have been more deeply impressed in the pedicle than in the brachial valve and in almost all specimens only the positions of the two main anterior trunks are shown. These originate at the border of the muscle scar, represented on the internal casts

[2] Herrick, C. L., A sketch of the geological history of Licking County, accompanying an illustrated catalogue of Carboniferous fossils from Flint Ridge, Ohio, Bull. Sci. Lab. Denison Univ., Vol. 2, p. 44, 1887.

[3] Whitfield, R. P., Contributions to invertebrate paleontology, Ann. N. Y. Acad. Sci., Vol. 5, Pl. 16, Figs. 7 and 8, 1891; reprinted in Report Geol. Surv. Ohio, Vol. 7, Pl. 12, Figs. 7 and 8, 1895.

[4] Hall, James, and Clarke, J. M., An introduction to the study of the genera of Paleozoic Brachiopoda, Paleo. of N. Y., Vol. 8, pt. 2, Pl. 47, Figs. 27 and 28, 1894.

[5] This collection was obtained incidentally during the course of field studies of the Pennsylvanian system made possible by a Grant-in-Aid of the National Research Council.

by a raised area, and extend forward at the top of the slopes which form the sinus of the pedicle valve. At positions about half way between the edge of the muscle scar and the margin of the valves the two main pallial sinuses branch for the first time. (Because of curvature of the shell and fore-shortening in the figures the position of the first division of these sinuses appears to be farther forward than it actually is.) The branching of the pallial sinuses takes place in a fairly regular dichotomous manner. The branches decrease in size with each division and finally disappear along a fairly regular line about two-thirds of a millimeter from the margin of the shell. At the first division of the two main trunks the inner branches descend into the sinus of the valve and their offshoots approach the margin of the shell at rather regular intervals across this depression. The two outer branches bifurcate two or three times in a similar manner and their offshoots spread out on the adjacent lateral parts of the valve. Altogether the ramifications of the two main trunks approach almost the whole anterior half of the periphery of the valve. In the case of the figured specimen the left trunk gave rise to eight and the right one to twelve small branches represented by minute ridges, and further division that has left no traces probably occurred.

The description of the two main anterior trunks of the pedicle valve applies also to the corresponding trunks of the brachial valve but in this valve the trunks are situated at the bases of the slopes which form the fold. The impressions of the pallial sinuses of the brachial valve, however, are not as plainly marked and all traces of them disappear at a greater distance from the margin of the shell.

A pair of lateral pallial sinuses was present in each mantle of the figured specimen although they are not as well shown on the cast as are the two anterior pairs. The lateral trunks originate near the areas of the muscle scars some distance behind the points of origin of the anterior trunks. On the brachial side they begin about one-half and on the pedicle less than one-third of the way from the forward edge of the scar to the cardinal margin. The lateral trunks extend forward and outward. Both of those on the pedicle side and the left one of the brachial remain unbranched to positions ⅔ or ¾ of the distance to the margins, but the right trunk of the brachial valve divides at a point about half way to the margin. All of the lateral trunks divide dichotomously two or three times and give rise to from four to six slender branches similar in size and spacing to those of the anterior trunks.

There appear to have been two pairs of posterior sinuses in each mantle. Their traces are very obscure on the figured specimen and

are better shown on another internal cast from the same locality. Like the anterior and lateral trunks these also originate near the borders of the muscle scars. The first pair of each mantle was directed laterally and the second pair extended outward and backward. It is probable that each of these sinuses branched once or twice although no traces of such branches are shown on the specimens.

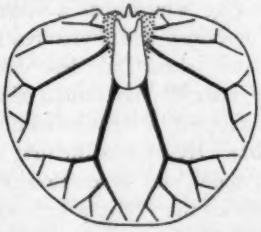

FIG. 3. A generalized restoration of an internal cast of the brachial valve of *Composita argentia* showing the arrangement of the pallial sinuses and the location of the ovarian areas. This pattern differs considerably from those preserved on specimens figured by Whitfield and by Hall and Clarke.

The surface of one or two of the larger internal casts is slightly raised and covered with small tubercules in two restricted areas upon either side and back of the raised area of the muscle scars on the brachial valve. These areas represent the ovarian impressions and indicate the position of the dorsal pair of genital glands. No trace of the ventral pair has been observed on any of the specimens; possibly these were contained to a greater extent in the pallial sinuses of the ventral mantle which may account for the plainer impressions of the pallial sinuses in the pedicle valve.

A number of specimens in this same collection have been broken and show the character and position of the brachidia which consist of two large, laterally directed spires, each composed of seven or eight loops. They were attached by short, delicate crura which in almost all specimens have broken, thus freeing the brachidia which now occur in various irregular positions. Beede considered similar irregularity in the postion of the spires in *Composita argentia* from the Western Interior basin to be the result of individual variation.[6] None of his specimens, however, show the crura and there can be little doubt that the irregular positions of the spires in his specimens also resulted from the detachment of the brachidia from the crura after the death of the animals and their displacement before fossilization occurred.

[6] Beede, J. W., Variations of the spiralia in *Seminula argentia* (Shepard) Hall, Kan. Univ. Sci. Bull., Vol. 1, pp. 155-157, Pl. 6, 1902.

In 1837 Dr. Charles Upham Shepard, Professor of Chemistry in the Medical College of the state of South Carolina, traveled by stage from Chicago to the village of Rockwell (situated just east of the present site of the city of LaSalle) where he remained for a short time. The following year he published a paper which was the first contribution to the geology of Illinois of any scientific importance.[7] In this paper were presented the first illustrations and descriptions of fossils collected in Illinois, among which was a species named *Terebratula argentia,* inadequately described and illustrated by two very poor wood cuts. Fourteen years later James Hall described and figured *Terebratula subtilita* from the Upper Pennsylvanian of northwestern Missouri[8] and this name has been adopted by most paleontologists for the common Pennsylvanian *Composita.* Keyes was the first writer to consider these two names to be synonymous and stated that *Athyris argentia* is "one of the commonest fossils of the (Shepard's) well known locality..."[9] Writing on this same subject later, Girty concluded that Keyes' statement that *"Seminula subtilita* is the commonest species at the locality where *T. argentia* was first found" is a "circumstance of importance, but scarcely . . . sufficiently conclusive to warrant the replacement of Hall's name, which has a definite meaning, for one whose significance is still vague and uncertain."[10]

Shepard's type specimen of *Terebratula argentia* is probably no longer in existence but his statement that it was obtained from "The limestone of the western bluff of the Little Vermilion" makes it possible to determine with reasonable certainty what species he actually had. The LaSalle limestone is extensively exposed and forms a conspicuous bluff along this stream and there can be little doubt, therefore, that Shepard's specimens were obtained from this horizon, although several other fossiliferous horizons of the Pennsylvanian outcrop at a few places nearby. In the fauna of the LaSalle limestone, or of the entire Pennsylvanian for that matter, there are only two species to which *T. argentia* possibly can be referred. These are, first, the form commonly cited as *Composita subtilita* and second, the one now known as *Squamularia perplexa.* It is true, as Girty has pointed out,[11] that Shepard's figures suggest the latter more than the former. All collections from the LaSalle limestone of this region, however, show

[7] Shepard, C. U., Geology of Upper Illinois, Amer. Jour. Sci., ser. 1, Vol. 34, pp. 134-161, 1838.

[8] Hall, James, Appendix E, Geology and Paleontology, *in* Stansbury, Howard, An expedition to the valley of the Great Salt Lake of Utah, p. 409, Pl. 4, figs. 1a-b, 2a-c, 1852.

[9] Keyes, C. R., Paleontology of Missouri, part 2, Mo. Geol. Surv., ser. 2, Vol. 5, pp. 93-94, 1894.

[10] Girty, G. H., The Carboniferous formations and faunas of Colorado, U. S. Geol. Survey, Prof. Paper 16, p. 406, 1903.

[11] Op. cit.

Composita to be much more abundant than *Squamularia*. A collection made at the quarry of the Alpha Portland Cement Company on the east side of Little Vermilion River only a few hundred yards from the place where Shepard's fossils were obtained contains 620 specimens of *Composita* and only 19 of *Squamularia*. Moreover, this and other collections from the LaSalle limestone reveal that specimens of *Squamularia* from this horizon are usually small and rarely attain a size equal to that of Shepard's figured specimen. On the other hand, *Composita* is commonly robustly developed, and numerous immature specimens equal in size to Shepard's type have not yet developed a conspicuous fold and sinus and cannot be certainly determined as *Composita* except by the absence of an open delthyrium and the presence of a foramen. Furthermore Shepard was a geologist of no little experience and his naming another species from LaSalle *Producta semipunctata* is evidence that he was familiar with paleontological literature which was not abundant at that time. Therefore his reference of the species *argentia* to the genus *Terebratula* rather than *Spirifer* is strong evidence that his specimen possessed a foramen and not an open delthyrium.

Hall's figures of *T. subtilita* are good and quite characteristic of certain types which are included within the common and variable Pennsylvanian species of *Composita*. However, Hall's designation of the type locality as "Missouri River, near Weston" is inadequate both as to horizon and precise locality and makes it impossible to obtain authentic topotype material which sometime may be desired to aid in a detailed stratigraphic study of these fossils. On the other hand the exact locality and precise horizon of Shepard's *T. argentia* are known and a large amount of authentic material may be collected from the extensive natural exposures and several large quarries which occur nearby.

In view of the above considerations it appears to be reasonably certain that *T. argentia* and *T. subtilita* are synonymous designations of the common Pennsylvanian *Composita* and as Shepard's name has priority this species should henceforth be known as *Composita argentia* (Shepard). Because of Shepard's poor illustrations and description and the loss of his type, some doubt must forever remain but Shepard may justly be given the benefit of this doubt in honor of his paper which was the first scientific contribution to the geology and paleontology of Illinois.

SOME NEW SPECIES OF CORALS FROM THE NIAGARAN STRATA OF THE HUDSON BAY REGION

BY

DENARD LEE

State Geological Survey, Urbana

Among the corals that were collected by Dr. T. E. Savage and Dr. Francis Van Tuyl in the area of the Silurian rocks outcropping to the west and southwest of Hudson Bay, the writer has found three new forms that he identified as belonging to the genus *Streptelasma.*

STREPTELASMA SAVAGEI n. sp.

Fig. 1

Corallum large, slightly curved, subconical, total length of a complete specimen unknown, the length of the holotype is 4.5 centimeters on the concave side and 6.5 centimeters on the convex side. The surface is marked by strong wrinkles of growth about 20 millimeters apart, between these larger wrinkles are from five to seven smaller, less distinct ones; all of these are marked by vertical ridges that correspond to the septa within. Calyx moderately deep, having at the fossula a wall 3 millimeters thick. Septa numbering one hundred thirty-four or more and alternate in size; the primaries extend to the center or two or more join before the center is reached. The inner ends of the primary septa are twisted into a pseudo-columella that is about 6 millimeters in height. Secondary septa greatly reduced in size and occupying the spaces between the primaries. Cardinal septum is in a fossula that is about 1 centimeter deep and 1 centimeter in width. Dissepiments few and flat or convex upward.

Probable length of a complete specimen at least 9 centimeters.

The greatest diameter of the corallum is 6.5 centimeters. At a distance of 6.3 centimeters below the calyx the diameters are 4.5 centimeters and 3 centimeters, the somewhat elliptical character of the cross-section may be the result of compression.

Holotype No. 857-F3 University of Illinois collection.

Niagaran:—Ekwan River limestone at Flint Rapids, Ekwan River, Canada.

STREPTELASMA EKWANENSIS n. sp.

Fig. 2

Corallum simple, large, tapering, and somewhat curved; the upper part of the corallum having less curvature than the lower part. The holotype measures 12.5 centimeters along the convex side, and the calyx diameter is 4.5 centimeters. The depth of the calyx is unknown but from the somewhat imperfect specimen at hand the depth was not more than 2.5 centimeters to 3 centimeters. The septa are of equal size; forty-eight were counted in two-thirds of the circumference of the calyx or about nine septa in the distance of 1 centimeter. The septa are thick towards the periphery, but rapidly thin as they pass towards the center; in some cases the inner edges of two or three septa unite before the center is reached. The walls between the septa are marked vertically with low rounded ridges which may represent faint secondary septa. Dissepiments concave, abundant, about eight in the distance of 1 centimeter near the outer margin; near the periphery they bend downward and towards the center they bend upward where, with the twisted ends of the septa, they form a vesicular or lacunose core. The external surface is marked vertically by ridges that correspond to the septa within, especially where slightly weathered.

Holotype No. 607-C8 University of Illinois collection. Paratypes No. 814-F1, 830-F2 University of Illinois collection.

Niagaran:—Ekwan River limestone about one and one-half miles above Limestone Island, Seven River, Canada; and at Upper Rapids and Flint Rapids, Ekwan River Canada.

STREPTELASMA TURBIMATUS n. sp.

Fig. 3

Corallum large with an average length measured along the convex side of 5.4 centimeters and along the concave side the length is 2.8 centimeters. The curvature is rather rapid in the basal part but becomes less rapid toward the upper part of the corallum. The greatest width of the calyx, which is at right angles to the plane of curvature, is 3.7 centimeters. The calyx is shallow, and in some specimens is compressed so that it is elliptical in cross-section. In the center of the calyx there is a distinct low pseudo-columella formed by the twisting together of the inner ends of the septa. The septa alternating in size, the longer reaching the center or two or more join and then pass on to the center; the secondary septa are much reduced in length and are sometimes obsolete. Dissepiments usually more than 1 millimeter apart and are flat. The exterior surface is marked by wrinkles of growth and vertical lines that correspond to the septa within.

Holotype No. 801-Fl University of Illinois collection.

Niagaran:—Ekwan River limestone at the Upper Rapids, Ekwan River, and a short distance above the first rapids below the mouth of the Fawn River, on the Severn River, Canada.

Remarks—Streptelasma savagei is characterized by its large size, sub-conical form, distinct growth markings and the comparative scarcity of dissepiments. *Streptelasma ekwanensis* differs from the former in that it tapers less rapidly, the wrinkles of growth are absent or indistinct, and the dissepiments are abundant and form, with the twisted inner ends of the septa, a prominent vesicular core. *Streptelasma turbinatus* is characterized by its turbinate form, being rather strongly curved in the basal part, and its shallow expanded calyx.

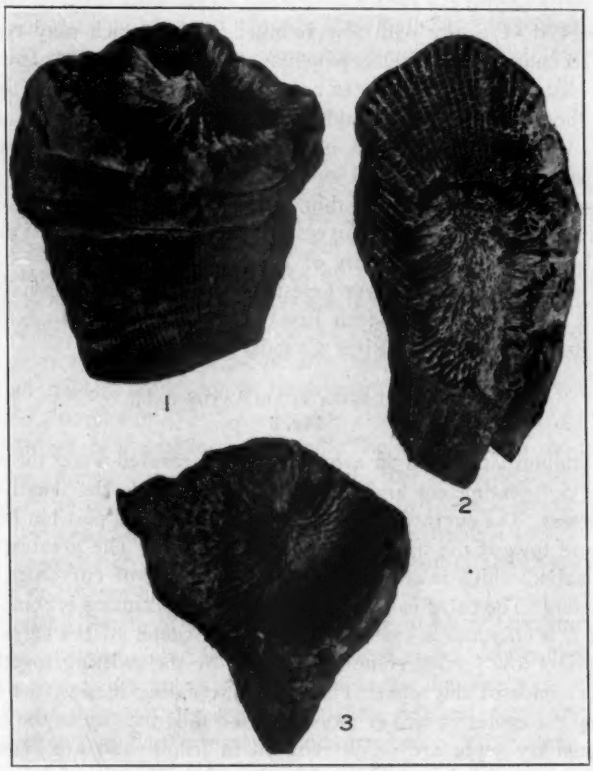

FIG. 1. *Streptelasma savagei n. sp.*
FIG. 2. *Streptelasma ekwanensis n. sp.*
FIG. 3. *Streptelasma turbinatus n. sp.*
(About four-fifths actual size.)

A STUDY OF THE NEW RICHMOND SANDSTONE FROM TWO LOCALITIES IN WISCONSIN

BY

C. E. NEEDHAM*

Northwestern University, Evanston

INTRODUCTION

The term *New Richmond* was first applied by Wooster[1] to sandstone beds at New Richmond, Wisconsin, without being very accurately defined. It has since come to mean the sandstones and thin interstratified dolomites constituting the middle formation of the Prairie du Chien, or Lower Magnesian group of Ordovician age, separating the Skakopee dolomite above from the Oneota dolomite below.

In connection with a detailed study of the New Richmond formation from well-cuttings on file at the offices of the Illinois State Geological Survey, the writer has carried on some study of the formation in Wisconsin. Two exposures are deemed worthy of discussion at this time, one of these at New Richmond in the northwestern part of the state, the other at Prairie du Chien in the southwestern part of the state.

EXPOSURE AT NEW RICHMOND, WISCONSIN

Section at New Richmond, Wisconsin, south bank of Willow Creek, at dam.

	Thickness Feet
Shakopee formation	
3. Dolomite, gray, in beds 2 to 8 inches thick; bedding irregular and wavy, shows algal structures; near the middle is a conglomerate of dolomite pebbles, some of which are edgewise; texture, fine to medium grained. The dolomite is sandy to a considerable degree; the lower part is somewhat cross-bedded	10
New Richmond formation	
2. Sandstone, white to pale yellow, friable, thin bedded and irregular; cross-bedded	1¼
Covered interval (a few inches)	
Oneota (?) formation	
1. Dolomite, gray, hard, fine grained, oölitic and slightly sandy..	1

* The writer wishes to express his thanks to Dr. A. J. Walcott of Northwestern University for his assistance rendered both in the field and laboratory.

[1] Wooster, L. C., Geol. of Lower St. Croix Dist., Geol. of Wis., Vol. IV, p. 106, 1873-79.

CHARACTER OF THE NEW RICHMOND

Texture

The New Richmond formation at this exposure is a fine grained sandstone with considerable quantities of both very fine and medium sand. Most of the grains are rounded to subrounded, but a few are subangular. Most of them show frosting and pitting, but little or no secondary enlargement. The texture is not uniform throughout the beds, but may change rapidly from layer to layer so that the proportion of medium grains is much increased. Dolomite is present in small quantities as tiny crystals between the sand grains, but it is seldom abundant enough to cement more than a very few sand grains together.

Petrography

Quartz grains constitute 99 per cent or more of the detrital material in this exposure. The remaining 1 per cent, or less, consists of mineral grains heavy enough to sink in bromoform (sp. gr. 2.8). Even though this heavy crop is very small it is interesting and instructive.

Garnet is the most abundant heavy mineral, making up about 45 per cent of the heavy crop. The grains are very fine, pink, and show considerable rounding. Some are smooth and polished, but others are pitted or rough.

Tourmaline is next to garnet in abundance, making up about 25 per cent of the heavy crop. It is found in very fine grains, all of which are well polished. Many of them are rounded, some are pea-shaped, and a few are elongated. The colors are brown and green; a few grains are blue.

Collophane, the amorphous form of apatite, is present to the extent of about 19 per cent. It occurs mostly as fine grains with a few of medium size, generally somewhat rounded and polished. The color is gray to an almost pale lavender tint. Under the microscope it is seen to be generally isotropic, but many grains show very feeble and non-uniform double refraction. Very tiny inclusions of double refractive substances are common. The centers of the grains are usually clouded whereas the edges are more nearly clear. The index of refraction lies between 1.6186 and 1.6196. Milner[2] points out that apatite carried into the sea as detrital material undergoes a degeneration. This may explain the condition of the apatite in this exposure at New Richmond.

Zircon, so abundant in the St. Peter and Dresbach sandstones, constitutes only about 9 per cent of the heavy minerals in the New Richmond. The grains are very fine, polished, nearly colorless, and rounded to subrounded; many of them are slightly elongated.

Ilmenite is not important as a heavy mineral in this exposure, although it may constitute as much as 1 or 2 per cent of the total heavy crop.

Galena is found as a few very small, fresh cubes. It is probably not detrital; it may have been introduced secondarily at the time of the mineralization resulting in the Upper Mississippi Valley lead and zinc ores.

The Exposure at Prairie du Chien, Wisconsin

The bluffs of the Mississippi River just east of the city of Prairie du Chien show excellent exposures of every formation from the Galena to near the base of the Oneota. The section for the Prairie du Chien group is as follows:

	Thickness feet
Shakopee formation:	
3. Dolomite, gray to light buff, fine grained, nearly free from sand; many small cavities filled with secondary calcite	**35±**
New Richmond formation:	
2. Sandstone, pale yellow, friable, slightly dolomitic; cross-bedded	**5**
Oneota formation:	
1. Dolomite, gray with some pinkish dolomite in lower part; much thin bedded and nodular chert; secondary calcite and quartz filling small cavities; a well defined algal zone is present in the upper half; occasional thin seams of green shale are found; the upper part of the formation is sandy	**200±**

Character of the New Richmond

Texture

At this exposure the New Richmond is a friable, medium grained sandstone with smaller quantities of fine and coarse sand. Most of the grains are rounded or subrounded, and many of them are frosted and pitted, the larger ones more so than the smaller. The grains show little or no secondary enlargement. Dolomite is present in greater or lesser quantity, generally in small, well defined crystals. In places the dolomite is sufficient to cement the sandstone rather firmly.

[3] Milner, H. B., Sedimentary Petrography, Second Edition, p. 439, New York and London, 1929.

Petrography

Quartz grains make up all but a small part of the New Richmond standstone. Many of them show tiny inclusions, undulatory extinction, and exhibit strain figures. This would seem to show that they were originally derived from igneous or metamorphic rocks. Many other grains, however, do not exhibit these features; they may have been derived originally from quartz veins, geodes, etc. Many of the grains show decided solution in the form of small, but often deep, embayments which are tightly packed with dolomite.

Feldspar grains are found in surprisingly large numbers in the sandstone. They may make up as much as 2 per cent of the total detritals. A few of the grains are slightly altered, but in nearly every case they are very fresh. They are subrounded and generally smaller than the quartz grains. Most of them are plagioclase, but a few are microcline.

Glauconite is abundant in a very thin, dolomitic sandstone band marking the contact of the New Richmond with the Oneota. This is particularly interesting in view of the fact that none of the Ordovician formations in the upper Mississippi Valley can be described as glauconitic. The glauconite grains are small, irregular, and spongy; they have every appearance of being autochthonous. The significance of this glauconite is pointed out below.

Among the heavy minerals garnet is by far the most abundant, making up about 90 per cent of the heavy crop. The grains are fine to medium, pink to red, and rounded to subrounded. As a rule the grains are not polished but instead show a peculiar roughened or pitted pattern on their surfaces, which may be a reflection of the dodecahedral cleavage.

Tourmaline is next to garnet in abundance, but it makes up only about 6 per cent of the heavy crop. The grains are larger than those from the exposure at New Richmond, but their characters are much the same.

Zircon is of very minor importance, making up 1 per cent or less of the crop. The grains are very small and well polished; most of them are slightly elongated.

Collophane is likewise virtually absent, usually constituting less than 1 per cent.

Galena is found as a few tiny cubes like those from the exposure at New Richmond.

Origin of the New Richmond Sandstone

The dolomite layers in the New Richmond formation, some of which are fossiliferous, according to Sardeson,[3] and the cross-bedded character of the sandstone show that the formation was laid down in shallow marine waters. No doubt some of the quartz grains were frosted by wind action before deposition in the sea. The great abundance of garnet and the well worn character of the tourmaline, zircon, and many of the quartz grains show that most of the sand has passed through more than one cycle of erosion. It is believed, then, that the New Richmond sandstone was derived largely from the Cambrian and pre-Cambrian sandstones of this region. But the abundance of amorphous apatite in the New Richmond exposure and the feldspar in the Prairie du Chien exposure are worthy of more than passing mention. It seems rather improbable that these two minerals could have survived a second cycle of erosion. Therefore, it is believed that a part of the sand was derived directly from the pre-Cambrian crystalline rocks to the east, north, or west. Furthermore, the freshness of the feldspar grains indicates that the climate, at least part of the time, favored mechanical weathering rather than chemical weathering.

Stratigraphic Relations

Most students have held that the three formations comprising the Prairie du Chien group are conformable one on the other. However, it has long been known that there is a distinct faunal break at the top of the Oneota, and Ulrich[4] feels that he has found evidence of an erosional contact at this horizon. Additional strong evidence of an unconformity between the New Richmond and the Oneota is afforded by the thin band of autochthonous glauconite found by the present writer separating these two formations. Goldman[5] especially has pointed out the significance of glauconite under these conditions. Consequently, the present writer is of the belief that the New Richmond formation is unconformable on the Oneota. As to the time value represented by this unconformity, the writer does not care to hazard an estimate.

Regarding the relation between the New Richmond and the Shakopee, there is no conclusive evidence that an unconformity exists between them. In fact, according to Sardeson,[6] some of the interbedded dolo-

[3] Sardeson, F. W., Fauna of the Magnesian Series, Bull. Minn. Acad. Sci., Vol. IV, pp. 92-101, 1896.

[4] Ulrich, E. O., Notes on new Names in Table of Formations and on physical Evidence of Breaks between Paleozioc Systems in Wisconsin, Trans. Wis. Acad. Sci., Vol. 21, p. 101, 1924.

[5] Goldman, M. I., Lithologic subsurface Correlation in the Bend Series of Northeast Texas, U. S. G. S. Prof. Paper No. 129, p. 3, 1921.

[6] Sardeson, F. W., op. cit.

mites of the New Richmond contain the same fossil forms found in the Shakopee. For the present, therefore, the two formations had best be considered as conformable.

Summary

1. The New Richmond formation of western Wisconsin is a white to yellowish, friable, medium grained, cross-bedded sandstone containing more or less dolomite.

2. The sand grains are mostly rounded to subrounded and frosted. Many of them show solution embayments filled with dolomite.

3. The most abundant heavy minerals are garnet, tourmaline, amorphous apatite, and zircon, in the order named.

4. Plagioclase and microcline are common in the exposure at Prairie du Chien.

5. The New Richmond is a marine formation deposited in very shallow waters. Some of the sand grains may have been wind blown before deposition in the sea.

6. Most of the sand was probably derived from sandstones of Cambrian and pre-Cambrian age.

7. Pre-Cambrian crystalline rocks, however, appear to have contributed directly to the sand, as evidenced by amorphous apatite and feldspar.

8. The freshness of the feldspars indicates climatic conditions such that mechanical weathering was favored over chemical weathering at least part of the time.

9. The New Richmond formation appears to be unconformable on the Oneota and conformable with the Shakopee.

RUINS AND PICTOGRAPHS IN NINE MILE CANYON, UTAH

BY

ALBERT B. REAGAN

Ouray, Utah

Nine Mile Canyon is a deep, east-west canyon, fifty miles east of Price, Utah. Ages ago it was inhabited successively by the Basket Makers, earth-lodge people, and a tower-fort building people. The last-named people built not only cliff-houses, with or without associated towers, but also squarish houses, forts, and towers in the open.

The forts were built on eminences that project from the mesa walls into the valley in such a manner as to give a commanding view of the canyon and surrounding heights. One of these forts which is on the north side of the canyon, about a quarter of a mile west of the Nutter ranch house has a wall forty-nine feet long, which extends from one side of the eminence on which it is situated to the other. Back of this wall are two houses, one of which is circular and was probably a kiva. Another fort across the valley to the southwestward is on a high and precipitous cliff about 200 feet above the valley and is built in the form of a quadrant of a circle, with its round side facing the canyon.

One of the several cliff-houses has a two-story, circular tower which is only seven feet in height and about four feet in diameter. The other towers (circular buildings) so far seen in the region are in clusters in the open and are not associated with other structures.

One group of these towers is on the top of a high mesa in an extremely dizzy situation. It is composed of three small stone circular structures, two of which are provided with roofs of heavy cedar logs and heavy flat stones. The logs and poles of these two structures would make about a cord of wood, and they possess distinct marks of the rude stone axes with which they were cut into suitable lengths. Another group is situated on almost inaccessible heights that command a magnificent view of many canyons. This group is composed of four circular stone buildings, one of which is somewhat larger than the others. These are so arranged upon the flat mesa top that the three smaller ones occupy the front and most exposed places on the very edge of the mesa, one of them being in advance of the other two. The larger stone structure is several yards behind the three smaller ones,

but from it a clear view of a wide and extended tract of country could be obtained. The only openings are at the tops, and their walls slope inward from the bottom, so that the opening in each of the small structures would allow the entrance of only one person.

Besides the different types of buildings in this valley, the ancients also left their rock writings on the canyon walls wherever there were suitable rock faces on which they could be pecked or painted, ranging from the valley floor to elevations of more than 500 feet. The drawings depict square-shouldered human beings, painted ceremonial scenes, animal scenes, hunting scenes, a fish trap (?), rain scenes, the playing of a game of shinney(?), scenes of turkeys being herded, turkeys in corrals, turkeys being fed corn, numerous snakes, and even horned (plumed or feathered) snakes. Most of them are much like and one exactly like the southwestern plumed snake drawings, snakes being prominent in more than half of the pictographs made by these people. Most of them are Pueblo scenes but one of the figures has his hair done up in the side-lock (or side-bob) fashion worn by the Basket Maker people. Whether the drawings of this type represent an invasion of a Basket Maker people into the Pueblo inhabited valley, or a people who were driven out by the Pueblo comers cannot be determined from the data at hand.

The forts, caches, cliff-houses, square-houses, and towers are, of course, Puebloan without question, although, on account of the scantiness of the pottery and its crudeness—usually a gray, plain ware, smoothed but not decorated, their horizon is hard to determine. However, the writer has no hesitation in considering them as falling in a late phase of Pueblo I or a very early phase of Pueblo II horizon of Pueblo culture.

The information contained in this paper was obtained while the writer was doing archaeological research work for the Laboratory of Anthropology at Santa Fe.

THE PATHOLOGY OF THE PREHISTORIC AMERICAN INDIANS OF THE ILLINOIS RIVER VALLEY

BY

HENRI STEARNS DENNINGER

University of Chicago, Archaeological Survey, Chicago, Illinois

The pathologic conditions encountered in the prehistoric American Indian are among the most interesting features of American archaeology. During the past four summers (1926-1930) the University of Chicago Archaeological Survey has been excavating Indian mounds in the Illinois River valley, and the material thus obtained has yielded a number of noteworthy pathologic specimens. Among these are five examples of Paget's osteitis deformans and a remarkable case of osteitis fibrosa, as well as fractures and congenital anomalies. Osteitis deformans, a chronic bone disease of unknown origin, occurs in individuals usually beyond middle age and affects from one to many bones of the skeleton, the skull rarely being uninvolved.[1] Osteitis fibrosa is related to osteitis deformans anatomically and pathologically, but it is distinct clinically and morphologically, and occurs in the earlier decades of life.[2] There is a recent tendency to group these two conditions, along with osteomalacia, under the clinical term of osteodystrophia fibrosa.

The skeletal material presenting these conditions is estimated to be approximately 1,000 years old. This chronological position is based upon the fact that the mound from which the skeletons were obtained belongs to the last of the three bluff cultures, which is intermediate between the Hopewell culture (2000 years old) and the beginning of the Columbian era.

This article is concerned with a hemimelic individual and the various types of fractures which we have encountered during the excavations.

A curious anatomic anomaly was excavated by the University of Chicago Archaeological Survey from mound F14, Fulton County, Lewistown, Illinois, in the summer of 1930.

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[1] Denninger, H. S., Paleopathologic Evidence of Paget's Disease, to be published in the Annals of Medical History.

[2] Denninger, H. S., Osteitis Fibrosa in a Skeleton of a Prehistoric American Indian, Archives of Pathology, June, 1931, Vol. 11, pp. 939-947.

This deformity, undoubtedly of congenital origin, occurs in the lower portion of the right humerus of skeleton F14-62, a female of approximately eighteen years of age. The right humerus is considerably smaller than the normal left, its greatest length being 26.8 centimeters whereas the left humerus measures over all 34 centimeters. Its shaft is ill-formed presenting only vaguely a few of the characteristic markings. The region of the deltoid tubercle is only slightly raised and roughened above the smooth level of the shaft. The musculo-spiral groove and curve are absent.

The head of the right humerus is a small irregular knob of bone about 3 centimeters in diameter. Its articular surface is roughened by two sets of concentric rings which correspond and fit approximately into a similar set found in the glenoid cavity of the scapula. The intertubercular sulcus is not present. The epiphyseal line between the head and shaft is still quite obvious and a similar demarcation may be seen on the left humerus.

Below the middle third of the shaft curious bone formations are to be found. The shaft flattens out here forming a spoon-like piece of bone with its concavity directed toward the median plane. This portion of the bone, if isolated, would suggest the acromial end of the clavicle. At the end of this there are three, possibly four, malformed minute articular surfaces. These most probably articulated with a small nodule of bone presenting an irregular array of small facets. Only one such piece was found but judging from its nondescript character and the arrangement of the facets, more than one of these bones must have existed during the life of the individual.

From the region where the flattening of the shaft begins there extends anteriorly a thin lamina of bone which gradually thickens as it progresses outward and assumes the shape of the very distal end of a young humerus. The size of this humeral-like projection is comparable to that of a normal humerus at the age of twelve. The lower portion of this projection is connected with the anterior edge of the spoon-like shaft by a bony ridge, thus leaving an elongated eliptiform space between the two.

Associated pathologic changes are found in the right scapula which is noticeably smaller in all its measurements. Its wing is very thin and wedge-shaped and the acromial process is about one-half the size of that of the normal left scapula. The glenoid fossa is atrophic being only about 2.5 centimeters in diameter and as previously mentioned presents a series of irregular roughened rings. The right clavicle is correspondingly small in size but contains no abnormal features. The

bones of the shoulder girdle as here described show little evidence of true retrogressive changes, but do indicate arrest of development at an immature stage.

During the excavation of the skeleton it was carefully noted that none of the bones of the forearm or hand could be found, and further there was no trace of evidence to even suggest that they had come into the grave, or had been possessed by the individual at death. Only the irregular nodule of bone noted was found in proximity to the distal end of the right humerus. These facts indicate that we are considering here a hemimelus, namely the absence of the right forearm and

Fig. 1. Photograph of skeleton F 14-62 in situ. The atrophic condition and peculiar formation of the lower end of the right humerus is clearly shown. Note the marked difference in size and shape between the humeri and the small bony nodule just below the distal end of the right humerus.

Fig. 2. Detail photograph of the anomalous humerus and bony nodule described in text.

hand. The latter are however probably represented in the small bony nodules already discussed. The possibility of a superimposed supracondylar fracture with healing in mal-position must be taken into consideration, for even with the congenital anomaly described such an accident to the arm at an early age would aid in accounting for the curious projection which so closely simulates the distal end of an immature humerus.

The evidence of fractures among these prehistoric people is not so common, in our experience, as would be expected. We have found

only five definite examples (all types) in a total of three hundred twenty individuals, or approximately 1.5 per cent. This paucity is striking in view of the 7.2 per cent of fractures of all types reported by E. A. Hooton in his study of the Pecos Indians.[3] In his series many present serious complications and sequelae such as non-union, evidence of infection, and excess callus formation, indicating as he suggests a belligerous origin, while our specimens show at most healing with mal-union. A more peaceful type of fracture, as it were.

The fractures of the long bones which we have encountered introduce essentially no features differing from those abundantly described in the paleopathologic literature, and a detailed description of them would hardly justify the repetition involved. We may note briefly, then, the following individual fractures.

One skeleton from the Parker Heights Mound at Quincy, Illinois, presented a semi-spiral fracture of the right humerus with two inches of overriding, little callus formation and retention of good position in the distal portion for the "carrying angle." In the Oakwood Cemetery Mound at Joliet, we encountered two individual specimens of long bone fractures in a group burial. One is an oblique fracture of the left femur, remarkably healed, with fair approximation, slight anterior bowing, and lateral rotation. The other is a splintered fracture of the mid-shaft of the left tibia in which the fragments healed in mal-union, with some anterior bowing and moderate callus formation.[4]
In a disturbed burial from Mound F 14 at Lewistown we obtained a healed fracture of the clavicle from an individual approximately eighteen years of age.

During the four summers work only one definite skull fracture has been encountered. It occurs in the skull of skeleton F 58-13 (adult) obtained from the Tampico Mound near Lewistown. The fracture is of the depressed type, being somewhat oval in shape (2.5 x 1.5 cm.) and located about one centimeter anterior to the coronal suture between the left inferior and superior temporal ridges.[5,6] The outer surface of the depressed bone fragment ranges from 1 to 3 millimeters below the external cranial table. In the process of healing, bone deposition has made the edges between the fragment and the external

[3] Hooton, E. A., The Indians of the Pecos Pueblo, A study of their Skeletal Remains, Yale Univ. Press, Chap. X, p. 312 ff, New Haven, 1930.
[4] Langford, G., has reported a number of interesting fractures from the Joliet region. The Fisher Mound Group, Successive Aboriginal Occupations Near the Mouth of the Illinois River, Amer. Anthro., Vol. 29, No. 3, 1927. Plates XI and XXXI.
[5] The diagnosis of linear, radiating, and puncture skull fractures is always a matter of considerable difficulty, particularly when there is no obvious or probable point of injury. Anti-mortem linear and radiating fractures must be differentiated from the simulating post mortem type of fracture produced by earth pressure in the grave, or the drying and warping fracture often appearing within forty-eight hours after excavation.
[6] Langford, *Op. cit.*, reports a possible arrow point wound of the right frontal bone, plate XXVII, p. 195.

table smooth and continuous. The inner surface of the fragment presents evidence of active osteogenesis, being heavily pitted and extending irregularly 6 to 10 milimeters below the ground level of the internal cranial surface. The lesion is situated over the cortical areas assigned to movements of the head and motor speech, and probably involved frontal branches of the middle meningeal artery. Although this individual lived after the accident, as evidenced by the healing, a discussion of his symptomatology would be exceedingly hazardous.

A PLEA FOR THE CAHOKIA MOUNDS

BY

WARREN KING MOOREHEAD

Phillips Academy, Andover, Massachusetts

One of the most beautiful of all Mississippi Valley Indian monuments—the Powell mound, which was located about a mile and a half west of the main group of Cahokia mounds—has recently been destroyed. Placed exactly east-west, steep, narrow and fifty feet high, the Powell mound was the most symmetrical tumulus that the writer has observed in seventeen states. Its destruction is a most lamentable loss to American archaeology.

During the surveys which resulted in the preservation of Monks Mound and other tumuli, Messrs. Cowen, Seever, and Myers, as well as the writer, urged the preservation of the Powell mound in a small separate park. Mr. Seever later offered to buy the structure and a small surrounding tract, intending to hold it until the State could reimburse him, but in spite of all efforts the mound was demolished. Gratitude, however, is due Dr. Arthur P. Kelly for making observations at the time of its destruction and for saving as much of the Indian material as possible.

Indiana has recently selected several mound-groups to be made into State parks, and Ohio has already exceeded all other states in appreciation of her Indian antiquities; the local parks and mound-groups are visited annually by thousands of tourists. The unfortunate loss of the Powell mound in Illinois should emphasize the necessity of protecting the remaining Cahokia mounds from further commercial developments. Monks mound, the largest known Indian mound, has been preserved for future generations, and the adjoining terraced mound on the Merrill estate to the west, a beautiful structure crowned with large trees, should be taken over without delay. Some tumuli lying east of Monks mound have been plowed over for generations, their surfaces lowered and their contours changed, but we have accurate descriptions of their appearance fifty years ago and it would be possible to restore them at a reasonable cost.

There is a growing tendency throughout the United States to protect and preserve our archaeological as well as our historical monu-

ments and shrines. Many of those already cared for have far less reputation than famous Cahokia, yet the commercial exploitation of Cahokia continues apace. Not merely all archaeologists, but thousands of our citizens who have seen Cahokia, join in earnest recommendation to the officials of the great State of Illinois that the remaining monuments of the famous site be purchased and preserved.

THE LARGEST KNOWN OSTRACOD

BY

HAROLD W. SCOTT

University of Illinois, Urbana

One of the most unusual ostracods that has ever been found was recently collected from the Galena dolomite of northwestern Illinois in the vicinity of Oregon, Ogle County. We ordinarily think of ostracods as minute crustaceans ranging in size from microscopic forms to forms a few millimeters in length. Specimens 15-20 millimeters in length are not common and are observed with considerable interest.

While studying the fauna of the Galena limestone the writer found a specimen of the genus Leperditia which measured 58 millimeters in length. This form attained a size more than twice that of any known species and is believed to be the largest ostracod that has ever been found. The largest known living ostracod, *Crossophorus africanus,* recently discovered in Africa, measures 15.5 millimeters in length. *Leperditia gigantea* Weller[1] attained a length of 22.5 millimeters and a height of 14 millimeters being heretofore the largest known fossil species in North America.

Leperditia titanica n. sp. probably represents the extreme development in size of any form of ostracod. The extreme size seems to be the natural development of a well established species. Smaller and younger representatives have not as yet been found, but it is believed that they will not be difficult to find when more collections are made.

LEPERDITIA TITANICA Scott n. sp.

Description—Carapace of extraordinary size, suboblong to subovate; anterior border semicircular; cardinal line straight, slightly shorter than greatest length of shell, forming an angle of approximately 110 degrees with the posterior extremity; a low ridge-like thickening occurs along the posterior half of the dorsal margin. Ventral edge of carapace broadly and evenly curved with a backward swing until greatest width of valve is reached where, due to the extreme size, the dorsal and ventral margins are subparallel for a short distance (this parallelism would not be apparent in smaller individuals), both an-

[1] Weller, S., Geological Survey of New Jersey, Paleozoic Faunas, Vol. III, p. 260, Pl. 23, 1902.

teriorly and posteriorly the margin is slightly raised to form a rather indistinct border. Surface of valve smooth, not pitted, evenly convex. Eye tubercule and muscle spot not distinguishable. Only right valve known.

Dimensions: greatest length, 58 millimeters; height, 33 millimeters; convexity of one valve, 3 millimeters.

Remarks.—The unusual size, angular extremity of the cardinal line, and even convexity of the entire carapace readily sets this species apart from any other. It differs from *L. gigantea* in its greater size, lesser convexity of the valves, more sharp backward swing of the ventral margin, and the presence of a raised border on the ventral edge. It has been suggested that this form might represent a branchiopod, but because of the general form, the convexity of the valve, and the rolled edge of the ventral margin, this seems improbable. Future discoveries may reveal details not shown on the material at hand.

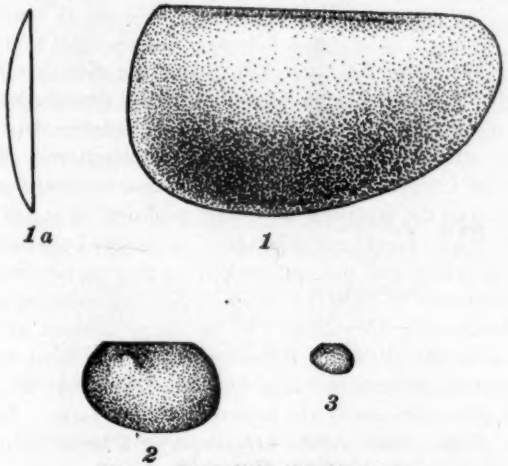

FIG. 1. Leperditia titanica n. sp.
FIG. 1a. Cross-section showing general convexity.
FIG. 2. L. gigantea Weller.
FIG. 3. L. alta.

The extraordinary dimensions and general characteristics are brought out in Figs. 1-3 where it is compared with *L. gigantea* and *L. alta*. *L. alta* is a well known and common form that can be considered as of ordinary size. All forms are shown natural size.

Formation and locality. Galena limestone; Ogle County, northwestern Illinois.

SOME NEW SPECIES OF *CAMAROTOECHIA* FROM THE BAINBRIDGE LIMESTONE OF MISSOURI*

BY

JOHN R. BALL

Northwestern University, State Geological Survey

AND

P. H. DUNN

University of Chicago

During the years 1923 to 1926, under the direction of the late Stuart Weller, the senior author has studied and described some of the fauna of the Bainbridge limestone of southeastern Missouri. The descriptions written at that time are in a manuscript filed in the libraries of the University of Chicago. A faunal summary and a possible correlation of the limestone have been published in one of the theses abstracts of the University of Chicago.[1] A study of the Bryozoa, and of the micro-fauna was not undertaken in this earlier investigation. During the summer of 1930 the junior author has collected extensively from the Bainbridge formation. In the large amount of additional material that he has secured it becomes evident that some modification of earlier conclusions reached regarding the fauna may be justifiable. Some of those modifications are presented in this paper. In addition, the studies of the junior author are revealing a large micro-fauna in practically all of the Bainbridge.

In the course of the earlier study of the Bainbridge fauna, three new species of *Camarotoechia* were described. Two of them are named *Camarotoechia indianoidea* n. sp. and *Camarotoechia neglectoidea* n. sp., respectively. These names were given in recognition of their striking resemblance to the well-known Silurian species from Indiana and elsewhere. With both of these Bainbridge species in the collections first studied were a number of closely related forms, rather sparsely distributed among the specimens. On account of their relatively rare appearance in the fauna, therefore, it was judged to be more conservative to regard them as but variants of the much more abundant species named above. *Camaratoechia neglectoidea* apparently had but one or

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[1] Ball, J. R., "The Faunas of the Brassfield and Bainbridge Limestones of Southeastern Missouri," The University of Chicago Abstracts of Theses, Science Series, Vol. V, 1926-27, pp. 261-269.

two variants but there appeared to be at least five related to *Camarotoechia indianoidea.* In the evidence afforded by the additional material that Mr. Dunn has collected it becomes quite evident that certain forms, previously regarded as variants, may be considered as distinct species of *Camarotoechia.* They are present in really significant number, and the particular differences that they possess are represented both in individuals that are young and also in mature representatives. It is the conviction of the authors, therefore, that some of the "variants" of the earlier descriptions may be set aside, and that one variant of *C. neglectoidea,* and three of the five variants of *C. indianoidea* may be elevated to specific rank. This reassignment of the forms recently restudied, leaves at present one variant remaining for *C. neglectoidea,* and two others that now are regarded probably as variants of *C. multiplicata* Ball and Dunn, n. sp., described in this paper. This study, accordingly, increases the number of new species of *Camarotoechia* in the Bainbridge fauna from three to seven, and makes the total number of Brachiopoda now known from the Silurian horizons of this locality fifty-nine.

Descriptions of the new species, including also those of *Camarotoechia indianoidea* and *Camaroteochia neglectoidea,* follow:

Class BRACHIOPODA Dumeril
Order TELOTREMATA Beecher
Family RHYNCHONELLIDAE Gray
Genus *CAMAROTOECHIA* Hall and Clark

CAMAROTOECHIA INDIANOIDEA Ball, n. sp.
Plate 1, Figs. 1-5

Description.—Shells small, subpentagonal, commonly wider than long, the greatest width about midway between the beak and anterior margin, the postero-lateral margins nearly straight or sometimes slightly concave, diverging at an angle of approximately 95°, the lateral margins nearly straight, the antero-lateral and anterior margins commonly straight but in some instances gently rounded. The dimensions of one individual are: length 11.8 mm.; width 12.5 mm.; thickness 7.6 mm.; greatest width of sinus 10 mm., greatest width of fold 8 mm.

Pedicle valve shallow, its greatest convexity in the umbonal region, the surface sloping abruptly from the umbo to the postero-lateral margins near the beak, with a gently convex curvature toward the lateral and antero-lateral margins becoming slightly flattened or concave near the margins. From beak to anterior margin along the mesial line the

curvature is regularly elliptical, while transversely the curvature is depressed convex. Originating near the base of the umbo, a broadly triangular and shallow mesial sinus, its surface slightly convex transversely, is produced anteriorly in a long and regularly rounded linguiform extension into the opposite valve. It usually bears three, sometimes four, low, broadly rounded plications, faintly discernable across the umbo, but evidently extending from the beak; on each lateral slope are three or four distinct plications with occasionally a few additional ones along the postero-lateral margins, all of them faintly defined posteriorly. Beak small, pointed, and slightly incurved.

Brachial valve thicker than the pedicle, its greatest thickness slightly anterior to the midpoint of the valve, the mesial region flattened transversely in the umbonal vicinity, the flattening continuing anteriorly into the broad mesial fold which originates in about the midpoint of the valve, and in some cases well toward the anterior margin. From the flattened umbonal region the surface descends almost at a right angle into the compressed, slightly concave postero-lateral surfaces. On each lateral slope the surface curves regularly and strongly from the umbonal region toward the antero-lateral margins with a curvature about equal to that in the mesial sinus of the pedicle valve. Along the mesial line from the beak over the umbo the curvature at first is strongly convex, then continues anteriorly in a flattened, gentle, convex line, in some specimens becoming slightly concave near the anterior margin. On the mesial fold commonly are four plications, well defined and subangular at the anterior margin, while on each lateral slope are three or four plications less conspicuous than those on the fold. All the plications extend from the beak but are faintly defined posteriorly. A distinct mesial furrow is well developed in the umbo and extends anteriorly across it. Beak broad, inconspicuous and closely incurved.

Faint concentric markings, sometimes present on both valves, generally are best developed near the anterior margin.

Observations. This species apparently is confined to what has been called the *"Merista"* bed in the Bainbridge limestone. Along with *Merista tennesseensis, Carmarotoechia neglectoidea* n. sp., and *Atrypina welleri* n. sp., it is one of the most prevalent brachiopods of that stratum and, like the first two of these named, it is noteworthy for the number of young specimens represented. It is quite similar to *Camarotoechia? indianensis* (Hall) and resembles that species in its variability of form; it differs from it, however, in its relatively more transverse outline, in the fainter development of its plications, and in the persistent occur-

rence of three plications in the pedicle sinus and four on the brachial fold. Individuals in the Bainbridge fauna with three and four plications, respectively, in the sinus and on the fold are so numerous in a collection of over three hundred specimens that they are here regarded as the prevalent and characteristic type of this species.

Location.—South slopes of Greither Hills, overlooking the St. Mary's road, two and one-half miles southeast of Ozora, Missouri.

CAMAROTOECHIA EXTANS, Ball and Dunn, n. sp.

Plate 1, Figs. 11-15

Description. Shells small, subpentagonal, length and width about equal, the greatest width slightly anterior to the midpoint, postero-lateral margins gently rounded, diverging at an angle of about 113°, lateral and antero-lateral margins regularly rounded, anterior margin nearly straight. The dimensions of two individuals, one of them the holotype, are: length 12.6 mm., 13.1 mm.; width 12.5 mm., 13.5 mm.; thickness 10.6 mm. and 7 mm.

Pedicle valve shallow, its greatest convexity in the umbonal region, the surface sloping abruptly from the umbonal region to the postero-lateral margins near the beak and with gentle curvature toward the lateral and antero-lateral margins, and greatly flattened along the lines of the plications bounding the mesial sinus. Along the misial line from beak to anterior margin the curvature is strongly elliptical, while transversely in the posterior region the surface is depressed convex and deflected downward abruptly at the lateral margins. A shallow mesial sinus, whose width at the anterior margin is about three-fifths the greatest width of the shell, originating at the base of the umbo, nearly flat or slightly convex transversely, is produced anteriorly in a lingulate extension into the opposite valve. In the sinus is a single plication, usually sharply angular, but sometimes faintly defined and extending from the beak: on each lateral slope are three or four low and rounded plications, those next to the sinus larger than the others. These plications also extend from the beak and in some instances there are more than four. Beak erect, small and pointed.

Brachial valve thicker than the pedicle, its greatest thickness in the midpoint of the valve, the surface depressed and flattened at the base of the umbo and on the fold. From the umbonal region the surface descends abruptly, almost at right angles, into a slight concavity on the postero-lateral margins, while along the lateral slopes the curvature from the umbo is strong and regular near the fold, but near the antero-lateral margins the surface is deflected abruptly downward into

the compressed surfaces of the margins. A somewhat narrow mesial fold, originating about the midpoint of the valve, bears two strong, well rounded plications extending from the beak, the mesial furrow separating them distinctly impressed along the umbo. On each lateral slope are from one to three low, simple and rounded plications, less distinct than those on the fold, also extending from the beak, although in some cases nearly obsolete. Beak broadly triangular, inconspicuous, and closely infolded.

Faint concentric markings are sometimes visible on both valves of the shells.

Observations. In average size and in general outline this species resembles *C. indianoidea* n. sp., and formerly was regarded as a somewhat freakish variant of that species. It is more sub-ovate than that species, however, the postero-lateral margins are more rounded, and it has but one and two plications, respectively, in the sinus and on the fold. It also resembles *C. bipartita* Ball and Dunn, n. sp., (Plate I, figs. 6-10) but in that species the plications in the sinus and on the fold are accompanied by fainter, secondary plications that are lacking in *C. extans.*

Locality. South slopes of Greither Hills, two and one-half miles southeast of Ozora, Missouri.

Camarotoechia bipartita Ball and Dunn n. sp.

Plate 1, Figs. 6-10

Description. Shells small, subpentagonal, length and width about equal, the greatest width at the midpoint of the shell, the postero-lateral margins nearly straight, diverging at an angle of about 102°, the lateral and antero-lateral margins gently rounded, anterior margin slightly angular. The dimensions of two individuals are: length along the fold of the brachial valve 14 mm., 11.4 mm.; width 14 mm., and 11.3 mm.; thickness 10 mm., 7.5 mm.; width of sinus at anterior margin 10 mm. and 7.5 mm.

Pedicle valve shallow, its greatest convexity in the umbonal region, the surface sloping abruptly from the umbonal region to the postero-lateral margins near the beak, and with a gentle convexity toward the antero-lateral margins, in some instances with an abrupt deflection downward at the margins. In many instances there is scarcely any curvature along the plications adjacent to the mesial sinus. A broad and shallow mesial sinus, originating in the umbonal region, whose width at the anterior margin is about three-fifths the greatest width of the shell, the bottom slightly convex transversely, is produced anteriorly as a sub-rectangular lingulate extension deeply into the opposite valve.

The sinus usually bears three plications, the mesial plication more prominent than the others, the two secondary plications sometimes but faintly developed, and occasionally one of the two is lacking. On each lateral slope are three or four low rounded plications, the ones adjacent to the sinus much larger and more angular, the others sometimes but faintly developed, or with all but one or two obsolete. All of the plications, including those in the sinus, extend from the beak. Beak small, pointed, and somewhat closely infolded.

Brachial valve thicker than the pedicle, its greatest thickness anterior to the midpoint of the valve, the surface flattened over the umbo and fold. From the umbonal region the surface slopes at first gently, and then abruptly to the slightly compressed postero-lateral margins. From the region of greatest thickness the surface slopes in the same manner laterally, descending with a pronounced deflection at the lateral and antero-lateral margins. A narrowly triangular mesial fold, originating in the umbonal region, bears on its flattened surface four low, rounded plications, which have developed by bifurcation from the two which extend from the beak, the plications separated equally by a prominent mesial furrow, the plications adjacent to the furrow sometimes more prominent than those lying along the margins of the fold. On each lateral slope the plications sometimes are three, all extending from the beak, but occasionally there are less than three, or the lateral slopes are smooth. Beak broadly triangular and inconspicuous.

Observations. This species tends to be slightly more robust than *Camarotoechia indianoidea,* although where the individuals of the two species are of about the same size, there is a striking similarity in general proportions and outline. It differs markedly, however, from *C. indianoidea* in that its plications in the sinus and on the fold are of unequal size, where in that species the plications are of equal development. It resembles also *C. extans* n. sp., in general outline and convexity, but in that species there are but two plications on the fold and only one in the sinus.

Horizon and locality. Bainbridge limestone, south slope of Greither Hills, Missouri.

Camarotoechia multiplicata Ball and Dunn n. sp.

Plate 1, Figs. 16-20

Description. Shells small, subovate to subpentagonal, width slightly greater than the length, the greatest width at the midpoint of the shell, the postero-lateral margins slightly concave, diverging at an angle of

about 95°, the lateral and antero-lateral margins regularly rounded, the anterior margin gently rounded. The dimensions of the holotype are length, 16 mm. width, 13.5 mm., thickness, 9.7 mm.

Pedicle valve shallow, its greatest convexity between the umbo and the midpoint of the valve, the surface along the mesial portion of the valve with strong and regular curvature from the umbo, but from the umbo towards the antero-lateral margins the surface descends at first with gentle curvature, and then becomes flattened considerably near the margins. From the umbo the surface slopes abruptly towards the postero-lateral margins near the beak, descending into a slight concavity on the postero-lateral margins. The same slight deflection occurs also at the lateral and antero-lateral margins. A broadly triangular and shallow mesial sinus, originating at about the midpoint of the valve, and occupying about seven-tenths of the greatest width of the shells, is produced anteriorly in a broad, lingulate extension into the opposite valve. It bears four low, rounded plications, all extending from the beak, with occasionally a fifth plication faintly defined. On the lateral slopes are from three to five plications, low and well-rounded, also extending from the beak. Beak, small, pointed and erect.

Brachial valve thicker than the pedicle, its greatest thickness slightly anterior to the midpoint of the valve, the mesial region somewhat flattened in the umbo, the flattening continuing anteriorly into the broad mesial fold. From the umbonal region the surface descends abruptly into the compressed, slightly concave postero-lateral areas; on each lateral slope the surface extends from the umbonal region in a strong, arcuate curvature to the antero-lateral margins. A broadly triangular fold, originating at about the midpoint of the valve continues with a slight convexity to the anterior margin, sometimes slightly deflected upward at the margin. It bears five low, well-rounded plications, the plications laterally on the fold sometimes less well developed than those nearer the center. All of the plications extend from the beak, and a fairly well defined mesial furrow extends from the beak to the anterior margin. On each lateral slope are four or five close-set, low plications, extending from the beak, but not always as distinct as those on the fold. Beak broadly triangular and infolded.

Concentric lines of growth sometimes visible near the anterior margin of both valves.

Observations. This species has the same general form as *Camarotoechia indianoidea* n. sp., but differs from it and from the other species described in this paper in respect to the greater number of plications that it possesses. It, like the *Merista tennesseensis* Hall of the Bainbridge fauna, exhibits some variability of proportions, a robust, some-

what elongated form appearing with those of the more transverse type. Several other individuals in the collections, while possessing a greater number of plications, have not as yet been described as distinct species. It is more probable, however, that they are variants of this species, if such they are, rather than variants of *C. indianoidea,* as originally named in the University of Chicago manuscript.

Horizon and locality. Bainbridge limestone, south slopes of Greither Hills, near Ozora, Missouri.

CAMAROTOECHIA NEGLECTOIDEA Ball n. sp.

Plate 1, Figs. 21-25

Description. Shells small, subpentagonal, wider than long, the greatest width about midway between beak and anterior margin, postero-lateral margins slightly compressed or concave, diverging at an angle of approximately 114°, lateral margins slightly rounded, antero-lateral and anterior margins straight. The dimensions of the holotype are: length 9.3 mm.; width 11.4 mm.; thickness 7.5 mm.; greatest width of sinus 6.6 mm.; greatest width of fold 4 mm.

Pedicle valve shallow, its greatest thickness in the umbonal region, the surface sloping abruptly from the umbo to the cardinal margins near the beak, but becoming greatly flattened over most of the area of the lateral slopes. Along the mesial line from beak to anterior margin the curvature is strongly elliptical, through a narrowly triangular mesial sinus which originates slightly anterior to the umbo, its surface nearly flat or slightly concave transversely, and is produced anteriorly in a long, linguiform extension into the opposite valve, its distal portion nearly at right angles with the general plane of the valves. It generally contains three, sometimes four, low, angular plications extending from the beak; on each lateral slope are from four to six plications, extending from the beak, slightly more prominent than those in the sinus with the exception of those nearest the postero-lateral margins. Beak small, pointed, and erect.

Brachial valve thicker than the pedicle, its greatest thickness near the anterior margin, the surface descending abruptly from the umbonal region to the cardinal margins near the beak and curving strongly and regularly over the lateral slopes along the fold and descending regularly from the fold toward the lateral and antero-lateral margins. The mesial region is flattened transversely across the umbo, the flattening continuing anteriorly along the long, triangular fold which develops at the umbo and which at the anterior margin is greatly elevated above the lateral slopes. From beak to anterior margin along the mesial

line the curvature is strongly elliptical at first over the umbo, and then becomes considerably flattened toward the anterior margin. The mesial fold bears four low, sharply angular plications all extending from the beak, with four or more less angular plications on each lateral slope. In some instances a mesial groove, developed on the umbo becomes on the fold a more pronounced furrow separating the plications than do the others. Beak relatively broad and closely incurved beneath that of the opposite valve.

Observations. This species, along with *C. indianoidea,* n. sp., is abundant in the *Merista* bed of the Bainbridge limestone. Superficially it is suggestive of *C. neglecta* (Hall) of the Niagaran of Lockport, New York, and of the Waldron, Indiana, beds, but it differs from that species in its greater size, its greater proportionate thickness, its strong transverse development and the larger angle of divergence between its postero-lateral margins. It differs from *C. indianoidea* in its transverse proportions, the angularity of its plications, the elevation of its fold and its narrower and deeper pedicle sinus.

Location. South slopes of Greither Hills, two and a half miles south of Ozora, Missouri.

Camarotoechia diversa Ball and Dunn n. sp.
Plate 1, Figs. 26-30

Description. Shells small, subpentagonal to subpyramidal, width and length about equal, the greatest width near the anterior margin, the postero-lateral margins distinctly compressed, diverging at an angle of about 90°, the antero-lateral margins gently rounded or subangular, the anterior margin nearly straight. The dimensions of two specimens, the first one the holotype, are: length 8.5 mm., 7.5 mm.; width 8.4 mm., 7 mm.; thickness 8 mm. and 6.2 mm.

Pedicle valve shallow, its greatest thickness near the umbonal region, but frequently the plications bounding the mesial sinus are so elevated at the anterior margin as to impart a subrectangular aspect in the lateral view of the valve. From the umbonal region the surface descends gently for a short distance over the lateral slopes and then becomes greatly flattened. From the umbonal region towards the postero-lateral margins the surface descends with but slight curvature at first, and then descends abruptly into a slight concavity on the marginal surfaces. A deep, narrowly triangular mesial sinus, originating at the base of the umbo, is extended anteriorly in a long lingulate projection into the opposite valve. It contains two distinct, subangular plications, both extending from the beak, while on each lateral slope

are three or four plications also extending from the beak, the ones bordering the mesial sinus usually a little more prominent and deflected sharply upwards at the anterior margin. Beak small, pointed and erect.

Brachial valve thicker than the pedicle, its greatest thickness at about the midpoint of the valve, the umbonal region slightly flattened and distinctly outlined in a triangular pattern by the pronounced compression of the antero-lateral margins. From the umbonal region along the lateral slopes the curvature is strongly arcuate, while a narrow, triangular fold is sharply elevated at the anterior margin. The fold bears three angular plications, all extending from the beak, and each lateral slope has two or three lower and angular plications, with incipient additional plications sometimes faintly developed. These plications also extend from the beak. Beak inconspicuous and infolded.

Observations. This species is more trianular in outline and much more compressed along the postero-lateral margins than *Camarotoechia neglectoidea* of which it formerly was regarded as a variant. Its plications are not as numerous as those of *C. neglectoidea,* and it invariably has two plications in the sinus and three on the fold where *C. neglectoidea* has three and four respectively. It resembles *C. neglectoidea,* however, more than it does *C. indianoidea;* and in its distinct and angular plications and with its extreme thickness near the anterior margin it appears more nearly related to the former than it does to the latter. In these respects it also resembles *C. neglectoidea* more closely than it does any of the other species described in this paper. The constancy of its number of plications in the mesial regions of both valves is a feature that appears in the young of the species as well as in the mature individuals. In the young individuals, however, the sinus and fold are not prominently developed.

Locality. South slopes of Greither Hills, two and one-half miles south of Ozora, Missouri.

EXPLANATION OF PLATE[1,2]

FIGS. 1- 5. CAMAROTOECHIA INDIANOIDEA Ball, n. sp.
Brachial, pedicle, lateral, cardinal, and anterior views of the holotype.
Holotype W. M. 22302
Paratypes N. U. 1232

FIGS. 6-10. CAMAROTOECHIA BIPARTITA Ball and Dunn, n. sp.
Brachial, pedicle, lateral, cardinal, and anterior views of the holotype.
Holotype W. M. 22343
Paratypes W. M. 22344
Paratypes N. U. 1234

FIGS. 11-15. CAMAROTOECHIA EXTANS Ball and Dunn, n. sp.
Brachial, pedicle, lateral, cardinal, and anterior views of the holotype.
Holotype W. M. 22306
Paratypes W. M. 22307
Paratypes N. U. 1235

FIGS. 16-20. CAMAROTOECHIA MULTIPLICATA Ball and Dunn, n. sp.
Brachial, pedicle, lateral, cardinal, and anterior views of the holotype.
Holotype W. M. 22342

FIGS. 21-25. CAMAROTOECHIA NEGLECTOIDEA Ball, n. sp.
Brachial, pedicle, lateral, cardinal, and anterior views of the holotype.
Holotype W. M. 22310
Paratypes N. U. 1233

FIGS. 26-30. CAMAROTOECHIA DIVERSA Ball and Dunn, n. sp.
Brachial, pedicle, lateral, cardinal, and anterior views of the holotype.
Holotype W. M. 22349
Paratypes W. M. 22350
Paratypes N. U. 1236

[1] All the illustrations are slightly reduced in size.
[2] The authors are indebted greatly to Mr. B. R. Millington, Northwestern University, for his assistance in the work of photography.

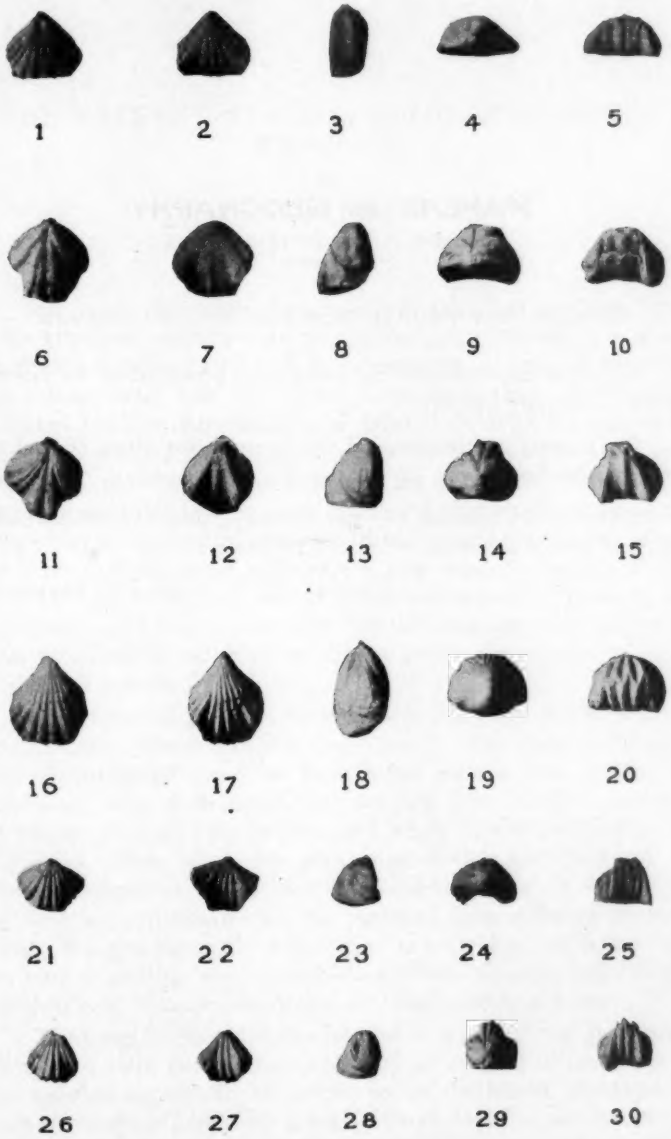
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PLATE I

PAPERS IN GEOGRAPHY

EXTRACT FROM THE REPORT OF THE SECTION CHAIRMAN

All of the papers herein published were presented at the meeting of the Geography Section.

The maximum attendance at the meeting was about 40 and the average attendance about 35.

Miss Mabel Crompton of State Normal University, Normal, Illinois, was elected chairman for next year's meeting.

(Signed) H. M. LEPPARD, *Chairman.*

THE PRESENT STATUS OF THE MISSISSIPPI PROBLEM

BY

W. H. HAAS

Northwestern University, Evanston.

Few people appreciate the stupendous task that confronts man in his attempted mastery over the Mississippi. The effort to make the stream more navigable and less destructive in time of flood has been a long, weary fight and the end is not yet in sight. Every effort at control has been attended by new difficulties. With the passing of the years subsidiary problems have become more numerous rather than fewer, until now there is held little hope for a complete solution. The appreciation of this fact has come slowly and only very recently. Conditions may be ameliorated and some of the subsidiary problems solved, but there probably never will come a time when the mighty Father of Waters will be entirely subject to man's commands. There is also a growing appreciation of the fact that the mounting costs due to increasing difficulties will soon exceed the productive capacity of much of the land protected.

One of the things to be kept in mind is that many of the problems related to the general control are man made. Man made in the sense that one attempted correction here brings about a new complication elsewhere. Man made also in the sense that there is little or no unity of interest to look at the problem as a whole and thus difficulties are multiplied. Even where one government bureau has charge of one line of development, it is difficult for another bureau to do what should be done because the two see the problems from different points of view. It seems especially difficult for an individual, no matter what his rank or position, to dissociate himself from alliances and look at a problem only from the standpoint of its solution as a whole.

The geographer is always interested in a project that promises to eliminate certain physical handicaps. In such so-called improvements the question uppermost, of course, is, are the results commensurate with the costs, will they pay a reasonable dividend on the investment? Small projects are for the most part profitable investments because the results may be fairly accurately pre-determined. They are found

profitable in large part, however, because the costs must be borne by those bringing about the change. If there is any erring it is usually on the side of being too conservative. In large projects, on the other hand, like that of the Panama Canal, or that of the Mississippi, there is always an uncertainty of results. Moreover, in such cases certain benefits may be derived which cannot be measured in dollars and cents. In the case of the Mississippi where these elements are present there is a tendency by those who benefit most to push the project so long as the whole nation can be induced to pay.

As no single agency has been willing to assume the cost burden it is not surprising that one of the most striking things in an attempted solution is the lack of united effort. This is strikingly evidenced when it is realized that six separate agencies have been building levees and that ten U. S. Government agencies have had authority in the development and control of streams.[1] This authority has been divided between the departments of War, Interior, Commerce, and Agriculture. It is really too much to expect that, working for separate ends, the officials should always be in harmony, working for the solution of the problem as a whole. In fact engineers have testified that their "plans have frequently conflicted with the general interests."[2] This status is very gradually and very slowly changing but the millenium is still far distant.

This lack of unity and the shifting of responsibilities from one group to another is only natural considering the evolution of the whole situation; and therefore the unification of interests is still one of the major problems.[3] Those who look to making the stream into a great commerce way work for their interests, those interested in flood control work for the things that benefit them. Unfortunately these interests, in many cases, are not only conflicting but actually antagonistic. This phase of the situation is of more recent development. The earliest pioneers in the region settled on the natural levee lands nearest the river. This area had not only better soil but was also nearer to a natural outlet. The river depth was adequate for the commerce, but the more or less annual floodings were a severe handicap. The solution for their problem was the elevation of certain levees. These private efforts gradually grew into group control, levee districts, and state control each with its own interests and ideas in the foreground relative to flood control. There were no conflicts.

The question of the part of the Federal Government in flood control came later and has never been settled. The War Department

[1] House Committee on Flood Control, Hearing, 1916, p. 191.
[2] Cong. Rec. 70th Cong., 1st Session, Pt. 6, 1925, p. 4254.
[3] Haas, W. H., The Mississippi Problem, a Conflict in Economic Emphasis, Annals Assoc. Amer. Geographers, Vol. 19, pp. 1-7, 1929.

early assumed authority over the river because of the vital importance of its navigability in time of war. Congress, however, has always strenuously opposed any participation in the flood problem, contending that the responsibility was local, not national. This responsibility has never been fully settled and has brought about many a bitter debate when appropriations were needed. There have been many arguments on both sides. The chief of these in favor of Federal control has been (1) that the War Department already has taken control of navigation and that the question of navigation and flood control can not be separated, (2) that the river was bought with the purchase of Louisiana and has never been parcelled out to the states, (3) that the magnitude of the problem makes of it one affecting the welfare of the whole nation, (4) that the waters of other states create the problems, and (5) that Congress through its increasing appropriation in recent years tacitly assumes such responsibility.

The part being played by the Federal Government in flood control has been actually forced upon it. It began with the introduction of the steamboat nearly one hundred years ago. The unfitness of the stream for the newer type of transport and the enormous toll of boats exacted led to an official survey for the possible elimination of hazards. The conclusion reached in this survey was that cross-currents in the stream caused undercutting of banks with resultant accumulation of snags and silt banks. A proper building of "dikes" (levees) it was urged would prevent cross currents, undercutting, and the silting up of the stream bed. From this beginning started the movement of the building of levees for the purpose of making the river navigable. This policy so strictly adhered to until the disastrous flood of 1927 has become quite famous as the "levees only" policy. It is to be noted especially that the participation of the Federal Government in the building of levees has been under the guise of aiding navigation.

With this policy has arisen a very strange and ineffective control of the river. The War Department has taken upon itself to keep the river at a depth of nine feet at all hazards. To invididuals, to local boards, or districts or states was left the problem of flood control. The one has been interested chiefly in the periods of low water, the other in the periodic floodings. The one has been interested in concentrating the waters into the narrowest possible channel to increase erosive power, the other has found that the progressive narrowing of the river bed between levees has been accompanied by a progressive rising in flood heights. Both sides have been levee building agencies but with an entirely different end in view. Now that the "levees only" policy has broken down the situation has been improved tremendously.

The general situation today is vastly improved over what it has been on the average in the past. The rapid development of the flood plain section, however, has intensified the clamor for better flood protection and a more effective outlet. For this reason also each new flood period brings about greater suffering. Before the Civil War considerable progress had been made in improving conditions, but during the war period everything gained seems to have been lost. In addition, during that and the reconstruction period there was a most remarkable series of floods, 1858, 1859, 1862, 1865, 1874, 1882, and each found the levees in worse condition than the one before. Toward the end of this period floods "went through and over" levees without restraint. To save the situation if possible, Congress created the Mississippi River Commission in 1879 to "improve and give safety and ease to the navigation thereof, prevent destructive floods,"[4] etc. The prevention of destructive floods, however, was not to be a dominant duty for the first appropriation in 1881 definitely stipulated that "no portion of the sum hereby appropriated shall be used for the purpose of preventing injury to lands by overflow or for any purpose whatever, except as a means of deepening or improving the channel of the river."[5]

During the 50 years of the commission's activity much has been done and much more could have been done but for the handicaps. The Mississippi River Commission, composed of three U. S. Army Engineers, one Coast and Geodetic Survey Engineer, and three civil engineers is only advisory in capacity. The Secretary of War, through the chief engineer, actually controls all construction. Up to 1917 all expenditures have been on a fifty-fifty basis, one-half supplied from local sources, the other half from the national treasury. From 1917 to 1927 the Federal Government has supplied two parts to one locally. Since the flood of 1927 with many of the districts bankrupt and with a debt greater than the present assessed valuations of the land protected, the Federal Government has been forced to take over the entire responsibility and expense. The Jones-Reid bill passed on May 15, 1928, held, however, that the principle of local contribution was sound, yet the U. S. Government, under the circumstances, should bear the entire expense for the present. The Commission is still advisory and the corps of U. S. engineers are still in a position to dominate. In the matter of control the present situation is not radically different from what it has been.

One of the most striking things in a study of this attempted control is the lack of plan. The lack of a unified organization and action; the

[4] House Committee on Flood Control, Hearing, 1916, p. 8.
[5] Quoted in World's Work, Vol. XXX, p. 236, 1915.

opportunist reaction to the sentiment of the day, which almost amounts to hysteria during flood periods; the lack of research by a scientific staff to discover causes; the lack of laboratories and a system of accurate measurements in order to procure accurate data necessary for a true comprehension and solution of the problem; the disregard for topographic maps, although through such large scale maps thousands of head of live stock could have been saved during the 1927 flood; the indecision and delay through congressional tactics, the idea that all research requirements are fulfilled when a group of congressmen with the title of Commission take a jaunt up and down the river; the indifference of the public at large except at periods of disaster; the muddling through the long series of years without the gathering and piling up of an enormous mass of basic data, all this seems incomprehensible.

Physically man has done little in turning natural laws to his benefit. The stream distance from Cairo to the head of the passes is 1060 miles. The shortest route from Cairo to the Gulf is less than one-half that distance; yet in this part, there are more than 2500 miles of levees, although there are no levees where the stream course is near the bluffs. The land in general slopes away from the river for five or six miles at the rate of three or four feet per mile, while the slope of the land toward the gulf is only about eight inches per mile, the gradient of the river being about three inches.[6] The gradient of the river varies greatly with the varying heights of the water but in the main the stream is at grade. The balance between aggradation and degradation is so delicate that the slightest change brings about the one or the other. The waters have been gradually hedged in more and more until the drainage waters of 41 per cent of continental United States, or 1,240,000 square miles, are concentrated upon a narrow belt of shifting alluvium less than a mile wide whereas the natural bed at flood periods was formerly 50 miles wide. This has been done, it must be remembered, not to redeem or protect overflow lands but to keep the stream navigable during the period of low stages. Little more is known relative to the laws underlying the above than was accepted half a century ago.

However, the point of view relative to corrective measures has changed radically since the disastrous flood of 1927. Up to that time the entire reliance was based on the building of the levees higher and wider and better. But the "levees only" policy has broken down. Levees have practically reached their limits, both structurally and eco-

[6] House Committee on Flood Control, 70th Cong. 1st Sess., 1927-28, Committee Doc. No. 17, p. 30.

nomically. After reaching a certain height the cost of building higher becomes prohibitive as the slope must be decreased from the order of about one on four to one on ten or even more. The upkeep is also tremendously increased. Structurally the height is limited also because of the character of the base upon which it is built, and the material available for its construction. Levees must be built with what is on hand and this is rarely even mid-grade levee material. Built on the natural foundation it may hold under a certain weight but give way when several feet are added to the height. When it is remembered that the average life of the levee is not more than ten years the cost of levee maintenance becomes so stupendous that the value of much of the area protected is by no means equal to the cost.

Even if the "levees only" policy has broken down completely, nevertheless levees are bound to play an important part always as far as we can see. For the present some of the existing levees are to be lowered, others to be raised somewhat. However, it has been estimated that to prepare for the next superflood, if the whole dependence should be placed in levees, the levee at Cairo would have to be raised twelve feet, the one at Arkansas City nineteen feet, the one at Angola twelve feet, and the one at New Orleans six feet. Such heights, it is believed, are entirely impracticable. To seek other means in flood control is, therefore, absolutely necessary.

The problem has been approached from two angles. The one is to slow up the waters before they reach the river, the other is to take care of the waters after they have reached the main channel. The one would slow up the waters by reforestation and the building of storage reservoirs, the other would increase the efficiency of the main channel by speeding up the waters or by providing more space for the flowing waters either between the levees or by providing spill ways either within or outside the outer levees.

There doesn't seem to be any effective way to slow up the waters sufficiently to be of material value. The Forest Service has recommended the acquisition of some 8,500,000 acres of land in the upper Mississippi Valley, but the retention of one inch of rainfall over this area would reduce the flood stage only one inch. The total amount of water in possible flood stages is so great (3,000,000 second feet, enough to fill Lake Erie in two weeks, and the flood stage in 1927 lasted forty-five days[7]) that the entire run-off for such an area would not materially affect the superflood stage. The capacity of possible water storage reservoirs is also relatively insignificant on this scale. To use these conjointly with water power projects does not seem feasible.

[7] Kelly, William, Am. Soc. of Civ. Engs., Paper No. 1709, p. 954, 1929.

Projects for the slowing up of the waters may be found helpful and feasible when in conjunction with other purposes but not for flood control alone.

One of the things that helps to narrow down the problem is that the superfloods are not caused by the rainfall in the upper valley. The floods are due rather to a series of lows that originate in Mexico or our southwest and pass up across Texas and more or less along the Ohio Valley. When the Mississippi, already high with the spring high water stage, is forced to receive in addition this run-off, a superflood stage is almost sure to result. Efforts to slow up the waters must therefore be concentrated in the Ohio basin and on other streams reaching the Mississippi south of Cairo. Work of this type may be alleviatory to a degree, but in no sense important enough to think of it as a solution.

The problem, therefore, is narrowed down almost entirely to the channel area below Cairo. The plans for this area have not yet been definitely fixed as the basic information is not available. The general plan is to remove certain bottle necks. It calls for additional water space horizontally rather than vertically. For example the levee between Cairo and Madrid will be lowered and a new and higher levee is to be built about five miles to the rear. The land between the two levees is to be cultivable in most years but not in superflood years, which come only every seven to ten years. To do this many complications naturally arise; the land in private hands will have to be bought, stream courses and roads will all have to be taken care of. The cost of protection, therefore, is mounting rapidly and the time will soon come when some of the leveed lands will have to be abandoned.

Another part of the plan is the building of spillways. In the section between the Red and the Arkansas it has been estimated that the levees would have to be raised twenty feet to be safe from the predicted heights possible. This is out of the question because of the problems arising. Instead there is to be built a so-called "fuse-plug-levee" about fifteen miles long which can be blown up when the danger line is being reached. The waters then will be permitted to reach the Gulf through the shorter channel of the Beuf River. The problem of course will be to prevent excessive erosion. However, the spillway is still about 60 per cent low timber country which will be left uncut in order to break the force of the water. These spillways will have to be leveed also, of course.

It is evident that the problem of flood control is by no means solved. Disregarding the transportation problem entirely which complicates the whole situation immensely, the whole problem requires the

most serious attention and research. One of these lines of research must direct its attention to a method of bank protection, effective but not prohibitive in cost. The time must come when the entire stream course between Cairo and the gulf will be revetted. Many of the bends are already protected but chiefly for the prevention of cut-offs. Another line of research and the more important of these two is the development of the stream course into a more efficient silt bearer. There are many possibilities here, possibly an unkinking of bends. Revetment will reduce the amount of silt from a third to a fifth. The elimination of present bends would almost double the gradient and increase the efficiency greatly.

In conclusion it may be stated that the present status as to a complete solution is one of pessimism rather than optimism, rather one of bewilderment than confidence. On the other hand, at no time have the prospects been brighter for a real scientific attack on the problem than they are at present.

SETTLEMENT AND DEVELOPMENT OF THE PRAIRIE PROVINCE OF ILLINOIS

BY

E. MURIEL POGGI

University of Illinois, Urbana.

INTRODUCTION

The Prairie Province as here used signifies approximately the area of early Wisconsin glaciation in Illinois (fig. 1). It was the early French settlers' "Grande Prairie," in which the native vegetation was mainly grass; forests covered less than 16 per cent of the area [1] (fig 2). In this paper the settlement of the area is discussed in four periods:

1. The period before the railroads, 1818-1850.
2. The period of the railroads and the Civil War, 1850-1870.
3. The transitional period, 1870-1893.
4. Recent changes and trends in the period, 1893-1930.

PERIOD BEFORE RAILROADS, 1818-1850

By 1820 Illinois had a population of more than 55,000, practically all within the forested areas where running water, fuel, and shelter were available. Owing to the lack of these necessities the prairies were looked upon as unfit for settlement. It was also common belief then that soil which supported trees must be superior to grassland.

About 1830 emigration set in from the northeastern states to Illinois. The opening of the Erie Canal gave impetus to this movement via the Great Lakes. The Illinois-Michigan Canal was not opened until 1848, but its influence was felt much earlier as towns were laid out along its course during construction. The population map for 1840 (fig. 3) shows that the sparsely settled Grande Prairie was encircled by denser population along the water courses. The discovery that prairie was good crop land aided immigration and by 1840 less than one twenty-fifth remained unsettled, the finest black soil of Champaign and Ford counties being the last to be opened up. Local supplies of timber largely controlled the settlement of these grasslands which

could not be sold unless several acres of forest land were included. The relative value of prairie and forest per acre was about one to seven [1].

In 1849 there was a rush of population away from the Wabash River settlements towards the center of the State which was to be traversed by the Illinois Central railroad. McLean County, owing to the abundance of undulatory timber land and its nearness to the older settlements of the Illinois Valley, was now rapidly taken up. The names Dry Grove, Blooming Grove (later Bloomington), and Funk's Grove

FIG. 1. *(Left)* Map of the glacial geology of Illinois according to Leverett. (After Sampson, H. C. An ecological survey of the prairie vegetation of Illinois, vol. 13, Ill. State Nat. Hist. Survey Bull. Art. 16, p. 530, 1921.)

FIG. 2 *(Right)* Original prairie and forest area in Illinois. (After Brendel & Barrows, vol. 13, Ill. State Nat. Hist. Survey Bull. Art. 16, p. 526, 1921.)

are significant. Few settlers ventured away from the timber before 1850 (fig. 3). Champaign County owing to its location in the heart of the prairie and consequent lack of timber did not attract settlers. Decatur, a mere hamlet in 1836, began to grow rapidly in the next decade due to the belief that a railroad was soon to be built through the town [2]. By 1850 the prairie section had become a dominantly rural area in which the great requirement was a market. Inland towns such as Bloomington could not furnish one because there were no lines

of transportation whereby the accumulated produce could be transferred to another large market for distribution. Not until the railroads from Chicago tapped this region was its future assured.

Previous to 1850 only beginnings of settlement were made in the Prairie Province. For several reasons the region was unattractive. First there was the lack of timber, secondly much of the land was swampy and required draining, third, although there were no trees to clear there was sod to break which was extremely tough and which

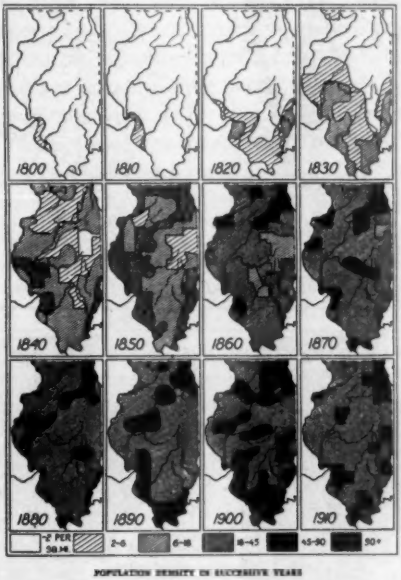


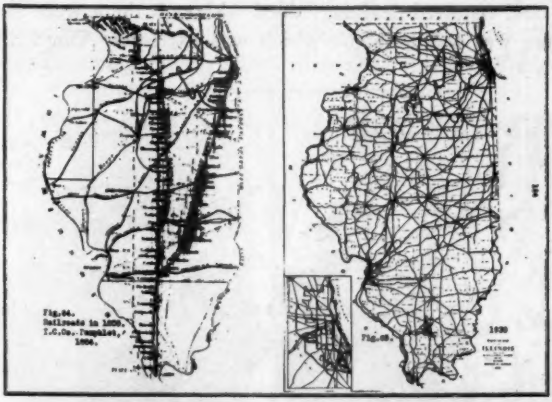
FIG. 3. **Series of maps showing the steady and rapid growth of Illinois in population for more than a century. (After Ridgely, Dougles C., *Geography of Illinois*, p. 146, 1921.)**

yielded but slowly to the plough. The greatest drawback, however, to settlement and development up to this time was the inaccessibility of the country owing to absence of navigable rivers and of roads, and consequent lack of markets [3].

PERIOD OF THE RAILROADS AND THE CIVIL WAR, 1850-1870

In 1850 Congress granted 2,500,000 acres of land to the State of Illinois, the proceeds to be used in the construction of a north-south transportation route across the State. This was the original Illinois

Central railroad. The main line traversed the western part of the prairie belt. The Chicago Branch gave direct connection between that city and the mouth of Ohio River, crossing the prairies on the divide between the Wabash and the Illinois. Thus the Illinois Central as completed in 1856, contributed two lines of communication across this



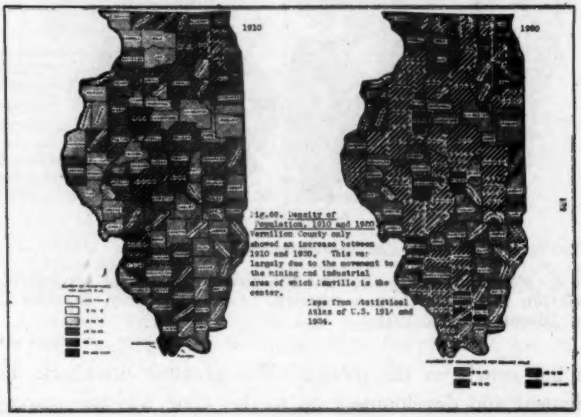


FIG. 4. *(Above)* Railroads in Illinois in 1855 and 1930.
FIG. 5. *(Below)* Density of population in 1910 and 1920.

section of the State. The Chicago and Alton, the Wabash, St. Louis and Pacific were also built at this time. Besides the railroads, the Illinois and Michigan Canal was completed in 1848 which provided another route. A transportation system with a primary commercial center at Chicago was thus established (fig. 4).

The Illinois Central did everything in its power to encourage immigration and the purchase of land. In 1855 the prices ranged from $5.00 to $25.00 an acre, "according to the location, quality and distance from the station." This was land which the United States government had offered for years without purchasers at from 62½ cents to $1.25 per acre [4]. Although of great fertility it had been practically valueless owing to lack of transportation facilities.

By 1860 Illinois had become the center of the agricultural life of the nation. During the Civil War the demand for food-stuffs for the Union armies, together with poor European harvests in that period served to stimulate prices. There was a withdrawal of a quarter of a million workers mainly from the farms of the State to join the Union forces. Men were a rare sight in the fields, women, children and negro "contraband" doing the work [5]. The use of farm machinery increased greatly. Because of the level topography, the prairie counties especially, came to be exploited by machinery. In Champaign County the value of farm machinery increased from $25,000 in 1850 to more than $600,000 in 1870. With the aid of this machinery the Illinois farmer in spite of large enlistments during the Civil War, increased his production of food sufficiently to meet the enormous demands of the eastern states during the decade 1860-1870.

The period from 1850-1870.was remarkable for the advance made in settlement and development in the Prairie Province. As a result of the railroads being built across the region the entire prairie, very sparsely settled in 1850, became in a decade a highly cultivated and productive part of the State. The year 1855 marked the close of steamboat supremacy in the Illinois valley. The early settler faced the river, from now on he faced the railroad. Timberland became relatively less important, while the open prairie came to be appreciated at its real value. The problem of the prairie had been solved, and almost every acre of what had hitherto been considered a useless section of the State was now utilized.

The Transitional Period, 1870 to 1893

During this period the population continued to increase, but at a slower rate. In the decade 1850 to 1860 the rate of increase was 101.1 per cent. During the twenty years 1870 to 1890 it was only 22.7 per cent [6]. By 1870 the Prairie Province everywhere had a population density of more than 18 to the square mile, except in the undrained marshland of the northeast. (Fig. 3.)

In 1860 the transition in this section, from the "self sufficing" stage, where the farmer produced practically everything he needed, to commercial agriculture where he specialized on a money crop, and bought his supplies, had been accomplished [7].

Until 1870 Illinois was primarily an agricultural State. Trade and manufactures were so dependent upon agriculture that their growth only served to accentuate its importance. In the period 1870 to 1890 the State rose to a high place of productivity in the fields of mining and manufacture in addition to agriculture. The importance of the latter cannot be gauged by the number of persons engaged in it, as the figures would lead to the conclusion that it was a declining rather than an expanding industry. The explanation lies in the fact that there was a transference during this period from the household to the factory.

The chief cereal crops in 1875 were corn, wheat, oats, and barley, in the order given. By 1890 the order was corn, oats, wheat, and barley. The wheat crop showed the greatest loss and was largely replaced by oats which were well fitted for production in a rapidly developing region. These two crops were utilized on the spot in feeding livestock, or in the production of prepared foods. The distribution of corn throughout the State during this period shows that the Province contributed the bulk of the supply. Sangamon County was the center of the Corn Belt in 1869, by 1879 it had shifted to McLean and by 1894 Champaign was the leading county, and the tendency to concentrate upon corn production in this section was very evident.

The early failure to utilize the mineral resources was due to the geologic structure and to the lack of transportation. In the central portion of the State the Coal Measures lie in a shallow syncline thickly covered with drift. Transportation of a bulky commodity like coal, over any great distance was impossible except by water, hence the most important mines and their markets were confined to the vicinity of streams during the pre-railroad period [8].

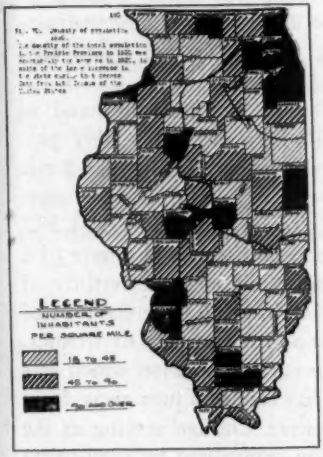
Coal was first mined on a commercial basis in the Prairie Province in Vermilion County in 1866. In the decade 1860-1870, the greatest growth among the 12 chief cities was made by Danville, 191.1 per cent, which illustrates the importance of this development. Vermilion was among the 5 leading counties for coal production in 1880, and has been among the first ten ever since. This county, however, is the only one in the Prairie Province in which mining is a major industry.

The changes during this period, though not as spectacular as those of the previous one, were none the less lasting in their influence. Increased agricultural efficiency, the beginnings of the manufacture of agricultural products and the rise of mining centers make it apparent

that this was a transitional period during which adjustments were being made preparatory to the State's great advance in industrialism which materially affected the population trends in the Prairie Province.

Recent Changes and Trends, 1893-1930

The most striking change in the distribution of population during the last 40 years has been the growth of the urban centers, which have absorbed most of the new comers and caused a decrease in the rural population in some counties (figs. 5 and 6). Statistics show, however, that during the decades 1890-1910, the apparently urbanization of the population proceeded rather from the extraordinary growth of



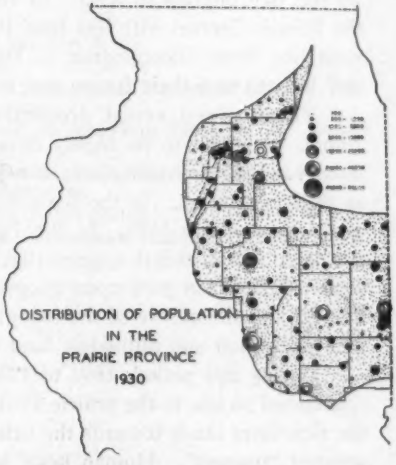


Fig. 6. *(Left)* **Density of population in Illinois in 1930. (Compiled from figures in 15th Census of the United States, 1930.)**
Fig. 7. *(Right)* **Distribution of population in Illinois' Prairie Province in 1930.**

Chicago than from a movement from the farms to the cities of the State as a whole. This was not the case in the latter decades, as the 1930 statistics show a marked increase in most of the urban centers. In the State there has been an increase in the average density per square mile, from 115.7 in 1920 to 136.2 in 1930. The increase in the Prairie Province has been much smaller, from 52.8 to 54. Even this is misleading as the only counties that show an increase in this section contain one or more cities which only emphasizes the fact that the urban centers have recently been drawing the population [9].

The map of the 1930 distribution of population in the Prairie Province (fig. 7) shows the rural type of settlement in this area. Apart from the towns of the Illinois Valley, which do not belong strictly to the Prairie Province and which have been treated elsewhere[1], there are only six urban centers with a population of over 10,000. Of these Decatur and Bloomington were on the original main line of the Illinois Central and later became important as railroad centers. Streator[2] and Mattoon developed as junctions on the east-west lines (fig. 4).

Danville's growth results largely from the coal and clay deposits. The importance of Champaign and Urbana is due to the location of the State University in the latter town, the site having been donated by Act of Congress in 1865. In 1854 Urbana was merely a depot on the Illinois Central with less than 100 dwellings [10]. Later the east-west line from Bloomington to Danville passed through Champaign and Urbana and their future was assured.

Tenancy and cereal production seem to go hand in hand in Illinois and tend to be highly developed where the soil is very productive. Only in such places can the soil support absentee landlords as well as farmers. In the State 42 per cent of the farms were operated by tenants in 1925. In the Prairie Province the figure was 55.7 per cent. From this it appears that the nature of the land tenure of a region depends in part upon geographical conditions—the fertility of the soil and the nature of the topography—which influence the type of land utilization and ultimately land values and the amount of tenancy.

During this period, 1893 to 1930, the rural population which was established so late in the prairie Province has begun to turn away from the rich farm lands towards the urban centers, Chicago serving as the greatest "magnet". Human labor has been supplanted by mechanical power which enables the individual farmer to work a larger farm, increase his output and dispense with many workers. This man power set free gravitates to the cities where it is absorbed by expanding manufactures.

In less than 100 years this area has developed from a region considered unfit for settlement into one where agriculture is extensively yet scientifically carried on, and where industries based upon agriculture are already well established. With sufficient power and excellent transportation available it seems likely that the Province, while using increasing amounts of its own agricultural products, will still have a

[1] Barrows, H. H., Geography of the Middle Illinois Valley. State Geological Survey, Bull. 15, Urbana, Illinois. 1910.

[2] Glass making at Streator is of comparatively recent importance. It is an extension up the Illinois-Vermilion Valley of the Ottawa industry which is based upon the presence of St. Peter sandstone.

surplus for sale outside the State. Agriculture will not decrease in importance but it will not stand alone as it has done heretofore. Judging from the recent population changes and trends in industrial development, Chicago will probably continue to take both the produce and excess population of the Province but increased industrial development may be looked for in the cities within the area such as Decatur, Danville, and Bloomington, which, owing to favorable geographic conditions, had an early start along industrial lines.

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PERIPHERAL ITEMS IN THE ARGENTINE PATTERN OF TERRENE OCCUPANCY

BY

ROBERT S. PLATT

University of Chicago, Chicago.

INTRODUCTION

The rich and youthful farming region of Argentina formerly known as the Pampas is characterized by uniformity of natural environment and by multiformity and changeability of land occupancy. Thus, for example, in the small district of Pirovano[1] in the interior of the province of Buenos Aires (fig. 1), the featureless fertile plain is occupied by a complex assortment of great estancias fattening beef cattle in alfalfa pastures, large farms fattening swine in corn fields, small farms raising wheat and other cereals, and minor sorts of productive activity. Moreover, these various activities all represent a change from the previous use of the grassy plain for extensive grazing and all show tendencies toward further changes in the future.

This superposition of variety of activity upon uniformity of environment is not unnatural but is based on uniform richness in the fertile plain, allowing success in various productive enterprises, easy success of one sort at the start and alternative opportunities for success in later stages of development in which final stability has not yet been attained.

These characteristics of the central farming region represent only one aspect of the Argentine pattern of terrene occupancy. At the margins of the region and beyond, the complex variety of land utilization gives way to simpler regional differences, by reason either of less richness or of greater maturity of development. The field studies reported upon herein are examples of occupancy in certain peripheral districts.

The greater simplicity of peripheral areas is less evident toward the shore than toward the interior margin of the central farming region. In fact, the shoreward margin may be considered to contain the very heart of the region, for settlement began along the shore, particularly

[1] This paper is the sequel of one entitled "Pirovano: Items in the Argentine Pattern of Terrene Occupancy," delivered at the annual meeting of the Association of American Geographers, December, 1930, published in the Annals of the Association of American Geographers, December, 1931. Both papers are based on field study in early autumn (March and April) 1930.

the northeasten shore including the river front; penetration of the interior took place from here, and the interests of the region have continued to focus here.

Vicinity of Rosario

Near this northeastern margin is the first of the items of occupancy to be discussed (fig. 1). The smooth rich plain extends to the very shore of the Paraná which here bounds the region. The land is, if anything, richer than that of Pirovano in the interior—the soil is more fertile, the rainfall more plentiful, the growing season longer, the winter milder, and the location close to the great port of Rosario is superior. No wonder that this margin—settled earlier and more densely than the interior and now somewhat more advanced in its development—should be considered the very heart of the central farming region.

The subdivision of property has progressed far (fig. 2). The great estancias, originally established as units of extensive grazing on the grassy pampas have all but disappeared. Even large properties which have not been divided in ownership are no longer functional units but are generally subdivided into tenant farms. Thus the present pattern of land division reflects organization of the area for cultivation of the soil in farms of a size to be operated by single families.

The form of land holdings reflects an original haphazard division of a featureless plain and more or less systematic subdivision thereafter, so that although there was no unity of orientation at the start, the later straight line boundaries generally form rectangular subdivisions.

One of the small subdivisions is the Chacra Zavalla (fig. 3), rented by an Italian immigrant from a larger property. It consists of a single cornfield 148 acres in extent, interrupted only by a 2 acre strip of alfalfa, a vegetable garden, and a corral grouped around the farm house.

The dwelling is a two-room brick hut located apparently at random in the midst of the flat cornfield (fig. 13). No other buildings are required. The farm machinery, ample modern equipment for producing the one crop, lies unsheltered behind the house. The eight farm horses are kept all year in the corral, fed on alfalfa or allowed to browse after harvest in the cornfield. No less important than the machinery and the horses is the farmer's family of seven children. With the farm all under one crop it is the family that supplies the concentrated demand for labor at harvest time.

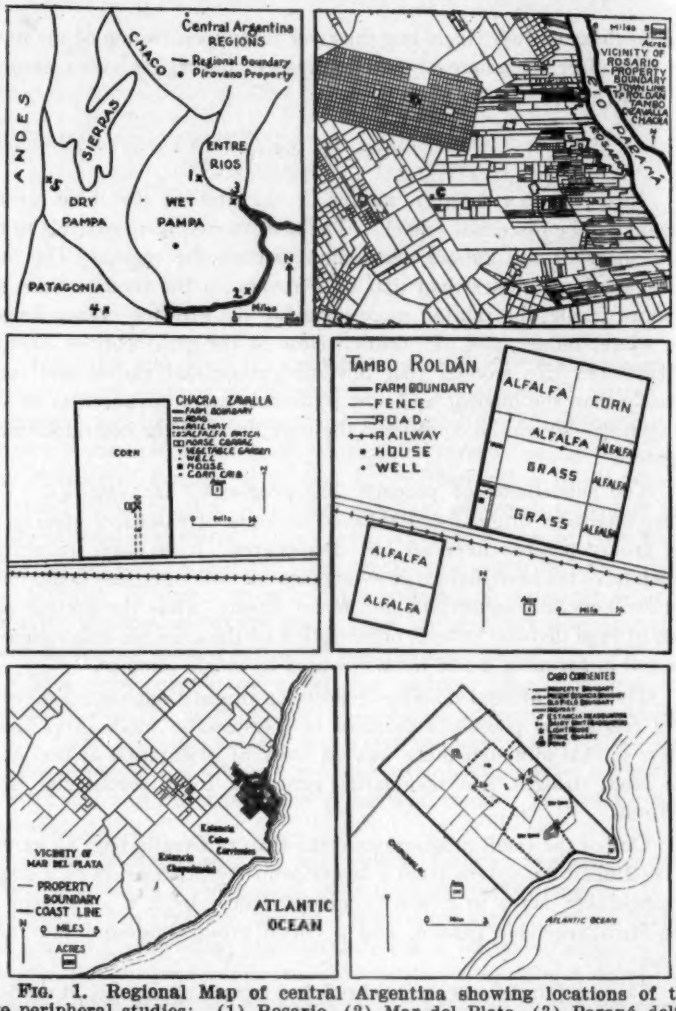

Fig. 1. Regional Map of central Argentina showing locations of the five peripheral studies: (1) Rosario, (2) Mar del Plata, (3) Paraná delta, (4) Choele Choel, and (5) Mendoza. The "Wet Pampa" is the Central Farming Region" referred to in the text. (Map based on Mapa de las Regiones Geográficas, Gastó n Federico Tobal, Buenos Aires, 1928.)

Fig. 2. District No. 1, vicinity of Rosario (fig. 1). This and the other four district maps (figs. 5, 8, 10 and 11) show areas of approximately the same size, in each case about 900 square miles.

Fig. 3. Map of corn farm in the vicinity of Rosario (figs. 2, 13).

Fig. 4. Map of dairy farm in the vicinity of Rosario (figs. 2, 14).

Fig. 5. District No. 2, vicinity of Mar del Plata (fig. 1).

Fig. 6. Map of Estancia Cabo Corrientes in the vicinity of Mar del Plata (figs. 5, 15).

The land is fertile silt loam with light subsoil and has produced corn continuously for years. When the annual rainfall reaches the usual amount of near 40 inches, the yield is commonly about 40 bushels per acre, but occasionally, as in 1930, a summer drought reduces the crop. The ears are gathered in bags and taken by wagon to a crib of cornstalks (fig. 13) near the house to await the arrival of a sheller in its round of the community. Then the shelled, bagged product, flint corn of export quality, is hauled to the nearby railway station for sale and shipment to the port.

This simple specialization in the best marketable crop which the soil will produce is a natural mode of procedure for a poor family occupying the land temporarily. But the system involves risk in the uncertainties of the one-crop yield, irregularities in labor needs, and inevitable depletion of the soil. As there are other possible crops and other farmers who are better off, this is not the only type of farming.

A less simple item in the pattern of terrene occupancy is represented by the Tambo Roldán (fig. 4). It is rented by a Basque immigrant who has some capital. The land is similar to that of the Chacra Zavalla, but contains a slightly depressed area that is poorly drained.

In the 351 acres comprising the farm, corn occupies one field of 47 acres, marketed like that of the Chacra but grown in rotation (fig. 14); alfalfa occupies 188 acres in 6 fertile fields, growing luxuriantly and available for pasture throughout the year, or for 5 cuttings of hay in summer, and maintaining itself for 5 years before replanting; natural grass pasture occupies most of the remaining 116 acres in the two poorly drained fields.

This combination is the basis for a dairy establishment of 80 cows. Calves are kept with their mothers and the products of the establishment are fattened calves and a moderate amount of milk which is taken to a nearby factory for the production of cheese and casein for export.

The only building needed on the dairy farm is a small house for the farmer and his family. It seems natural that this establishment with its easily productive and accessible land should be a prosperous contributor to a world market.

The Tambo Roldán and the Chacra Zavalla represent characteristic land utilization in the vicinity of Rosario. Obviously the one-crop farm is not a permanent establishment, but it is a short step from this to some sort of stable combination of grain, pasture and livestock such as that of the tambo. Already the chacra has a few pigs. Thus the pattern of occupancy seems to be approaching the uniformity and

stability of mature development in this marginal heart of the central region. Let us pass to a second point in the periphery (fig. 1).

Mar del Plata

The outermost cape of the Argentine coast is peripheral in a very literal sense, even though it lacks a peripheral spirit even more than does the district first discussed. Rosario at least is distinguished as a marginal focus, whereas the rural area of Mar del Plata has developed as an undistinguished part of the interior, reached by an overland journey from the northeast coast and only recently opened to secondary access through the port of Mar del Plata. Its pattern and stage of development are like those of the interior of the province.

The pattern of property division (fig. 5) almost duplicates that of Pirovano. The orientation is that of the distant northeast shore, the straight lines and right angles are those of the featureless plain, and there are both large properties of the old pastoral era and small properties of agricultural settlement. Like the interior, and unlike the Rosario margin, some large properties are still functional units.

Two large properties exemplify the pattern of occupancy. Estancia Cabo Corrientes carries the name of its ocean promontory (fig. 6). How sharply the Argentine plain meets the sea without intervention of other land forms is suggested here where smooth farmland extends uninterrupted to the lighthouse at the water's edge, even on this most prominent cape of the long coast (fig 15). Cabo Corrientes marks the place at which a low ridge formed of underlying limestone succeeds the almost flat alluvial lands extending southward from the Paraná and Rio de la Plata. Thus the land of the estancia, like that adjoining it on the south and inland from this point, is an undulatory upland with rock but a few feet beneath its silt soil.

The estancia has an area of 18,000 acres, with a seashore frontage of 4 miles. It was founded 50 years ago as a grazing establishment, and continued so until recently. Now the rise of new opportunities has led to changes. The soil and climate are good for agriculture and under the market stimulation of the town and new port of Mar del Plata, 12,000 acres have been subdivided into small farms and rented to immigrant tenants. The larger of these subdivisions are grain growing enterprises, in some cases a single farm occupying one of the old estancia pasture fields with 1,200 acres as a maximum size. Wheat and oats, some barley and a little corn are grown for market. Smaller tracts, commonly 120 acres, are rented for the more intensive and soil-depleting crop of potatoes.

The remaining 6000 acres of the estancia have been kept intact by the Argentine owner to form a dairy establishment with a total of 2600 cows. The land is less suitable for alfalfa than are those of Rosario and the western interior of the region with their lighter soils and higher water table; but the natural grass is good pasturage and other available plants make excellent fodder for cows. The establishment has been organized into seven dairy farms, to eliminate the difficulties of inconveniently large herds and too extensive tracts of land (fig. 6).

The dairies are not all of the same size, but a typical one has 350 acres of land, 125 cows, and seven men. The only dairy building is a house for the men, beside which the milking pen and water tank complete the dairy headquarters. The cows remain in pasture throughout the year. As the natural grass is less efficient for milk production than selected pasture plants and is particularly poor during winter cold and summer drought, more than half of the land allotted to each dairy, adjacent to headquarters, is planted pasture. A mixture of barley, rye and oats is particularly good for winter pasture, and corn provides green summer fodder. The planted land is divided into six fenced fields, of an average size of about 40 acres, each used for about two months during the year. The dry cows, which need not be kept at the dairies on special fodder, are segregated elsewhere in large pastures of natural grass (fig. 15).

The estancia specializes in providing fresh milk to the Mar del Plata market, thus taking advantage of proximity to the city and of high grade production methods. Calves are not kept for fattening but heifers are reared to replenish and increase the herds.

The establishment is a profitable enterprise, and is expanding steadily over more of the old estancia property, displacing some of the small tenant farmers who hold leases for only one or two years. Thus apparently befitting its natural setting this new use of the old estancia shows evidence of stability.

Further illustration of land occupancy in the district is provided by the neighboring property of Chapadmalal, probably the most famous estancia in Argentina (fig. 7). The land is like that of Cabo Corrientes, in the same undulatory, fertile plain, originally grass covered and long used for extensive grazing. Of the 30,100 acres contained in the old estancia, 17,800 have been subdivided into small farms and leased, as at Cabo Corrientes, the remaining 12,300 acres being kept intact to form the present estancia.

It is not the land but the type of activity here engaged in which has distinguished the establishment. Chapadmalal has been developed by its Argentine owner for the breeding of fine livestock, pedigreed

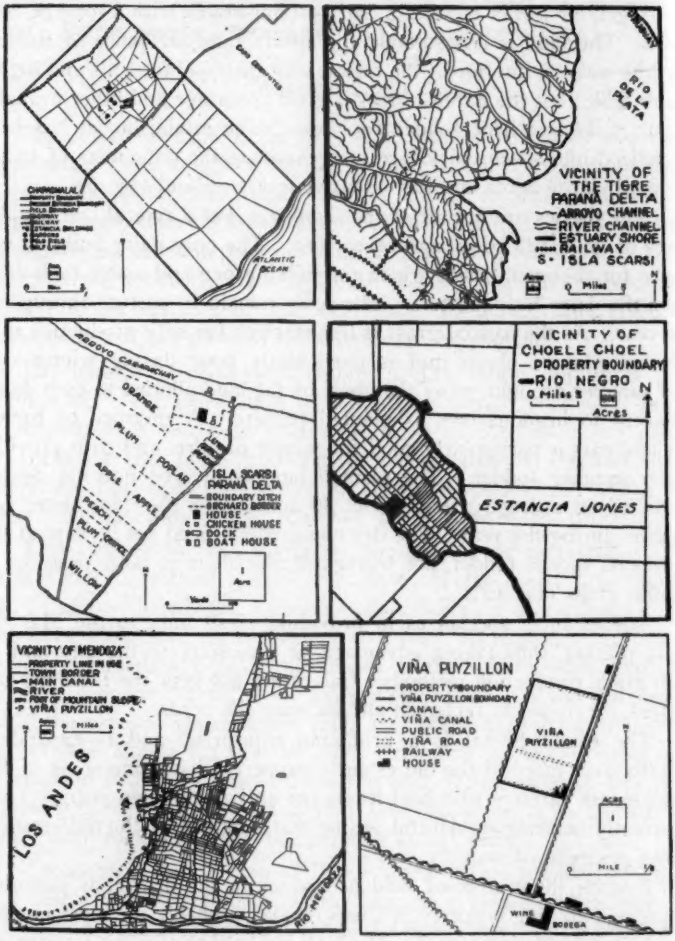

Fig. 7. Map of Estancia Chapadmalal in the vicinity of Mar del Plata (figs. 5, 16).

Fig. 8. District No. 3, vicinity of the Tigre or southern corner of the Paraná delta (figs. 1, 17).

Fig. 9. Map of fruit farm in the Paraná delta (fig. 8).

Fig. 10. District No. 4, vicinity of Choele Choel (figs. 1, 18).

Fig. 11. District No. 5, the north-central part of the Mendoza oasis (fig. 1).

Fig. 12. Map of vineyard in the Mendoza oasis (figs. 11, 20).

bulls and race horses (fig. 16). Ordinary beef steers, 2,000 or more in number, occupy large outlying pastures of natural grass, but chief attention is given to the less numerous but far more valuable pedigreed animals. These are carefully attended, pastured in small planted fields, and housed in stables. For pasturage 2,900 acres are planted with mixtures including rye grass, blue grass, and clover. For winter pasture 1,200 acres are planted in oats. The number of animals is only a little larger than at Cabo Corrientes, although the amount of land and the number of workers, 120, are twice as great.

The estancia sends many winners to livestock shows and horse races, selling its output at premium prices and maintaining a high reputation in a country where livestock is greatly esteemed. But it has been a costly venture, marked by considerable extravagance, so that it has passed under the control of creditor banks. Probably there will be changes of policy, but in general the establishment seems to be of a type befitting its natural setting, fulfilling successfully a special need of national significance, and enjoying the advantage of an established reputation.

Apparently there is a permanent place in the district for at least one fine breeding establishment, as well as for some beef cattle and some dairy establishments and farms utilizing the soil for agriculture. This suggests some approach to stability. But it seems unlike that of Rosario where intense and long continued activity has led toward mature development. Near Mar del Plata activity has been less and changes have been slighter from the livestock grazing of the original occupancy to the grazing of the present, part of it still on the natural grassland. Here, apparently, stability after less change accompanies less richness of opportunity. As the soil is unsuitable for alfalfa and less outstandingly productive for other crops, although supporting excellent grass pasture, there is no strong incentive for final change to intensive forms of agriculture and livestock fattening.

So much for the first two districts under discussion, both within the periphery of the central farming region and both sharing certain aspects of its complex variety of development.

Delta of the Parana

The remaining districts lie beyond the margin of the region and are different from it. One of these, the third in our discussion, is barely beyond the margin (fig. 1). It is so small that it would commonly be considered as an insignificant marginal appendage, and is so close to Buenos Aires, the urban focus of the region, that it is almost a part of it.

At Buenos Aires the lowland plain of central Argentina is bordered by a broad estuary, the Rio de la Plata. A few miles northwest of the city the central plain ends just as definitely in a low *barranca*, but beyond its edge is a maze of islands and narrow channels, the delta of the Paraná, at the head of the estuary (fig. 8).

Here the pattern of occupancy is distinctive and unlike that of the adjacent plain. Instead of rectangular properties hundreds or thousands of acres in extent, here are irregular island properties, in many cases minute sectors of small islands.

Such a sector of an island is the Isla Scarsi (fig. 9), a property of 10 acres fronting on one of the river channels (fig. 17) and extending back to swampier land in the center of the island. As its name implies, the Isla Scarsi is itself practically an island, bounded like its neighbors by drainage ditches. Only in recent years and only in a specialized way has this land been cleared and put to use, unsuited as it is to easy or extensive farming operations.

Under the conditions, horticulture has been found suitable. Intensive crops responsive to special treatment are favored here where the land is fertile, limited in extent, difficult to work and requires a system of drainage ditches. Moreover, frost hazards are lower on the delta islands close to warm river water from lower latitudes than on the open plains, and Buenos Aires, on the edge of the plains and close to the delta, provides a market for fruit. Therefore fruit is grown by the Italian settler at Isla Scarsi as well as by most of his neighbors. With the development of the district, marketing has been facilitated by the establishment of a cannery on a nearby delta island.

A natural levee near the river forms the highest part of the Scarsi land. Here is the oldest part of the orchard, started with a planting of oranges. Only hardy oranges can be grown and most of the Argentine supply comes from subtropical areas farther up the river. The middle latitude fruits are more important here.

Since the first planting at the Isla Scarsi, land progressively farther and farther from the river has been cleared, drained, and planted. The interior is not lower than the river except at times of very high water and usually the main ditches drain from the swamp into the stream. But secondary orchard ditches drain into the swamp.

Fruit planting has left only a small grove of willow trees at the swampy end of the property and a patch of poplars near the house. Willows and poplars, either planted or growing wild on the unimproved delta land, provide a fairly profitable harvest as fuel for the nearby metropolis on the coal-less and treeless plain. But the yield from fire-

wood is too low for good land and the larger amounts come from less developed outlying parts of the delta.

A final phase of delta development is as a place of recreation for the city, having attractions of waterways and woods unique in the vicinity. Accordingly the Isla Scarsi is an open-air restaurant and picnic ground, and the income from this source is almost as great as from fruit. All transporation, whether of fruit, firewood, or pleasure seekers, is by the network of waterways (fig. 17) connected with the outside world by a railway terminus on the delta margin.

In none of these respects are great changes in prospect for the delta district. In spite of close relations with the nearby urban complex relative simplicity and stability of development seem to have been readily attained in this area of special and limited possibilities.

Choele Choel

Upon turning from the shoreward to the landward side of the central farming region much greater areas of special and limited possibilities are in evidence. Bordering the central region is an expanse of semi-arid bushy plain. In this area far out beyond the margin of agricultural land is the 4th district to be considered (fig. 1).

The fact that this district is included in Patagonia and not in the dry pampa adjoining the farming region does not mean that it is different in itself from the rest of the semi-arid belt. In fact, northern Patagonia would probably be considered as an integral part of the semi-arid belt if it were not for the fact that it lies west of a semi-arid coast instead of a wet fertile coast and therefore has had a political history and regional relations different from the area immediately north of it. Practically it is now a coherent part of the dry western plain.

Choele Choel on the Rio Negro is unlike a great majority of places on the dry plain in having a concentrated source of water (figs. 10 and 18). The island of Choele Choel is a newly formed oasis in the semi-desert region, a floodplain area partly protected by dikes and recently irrigated by canals from the river. The relative intensity of its agricultural development is indicated by the subdivision of property; most of it is in farms of about 250 acres with alfalfa as the chief crop, and some of it is in farms as small as 12 acres devoted to apples, grapes and other fruits, like orchards of the Paraná Delta in size and products.

Except for this recent island development almost all the land in the vicinity is unirrigated. The pattern of property division suggests the contrast in land occupancy. Single properties are larger than the total area of irrigated land on the island. One of these land holdings offers an example of occupancy in the district.

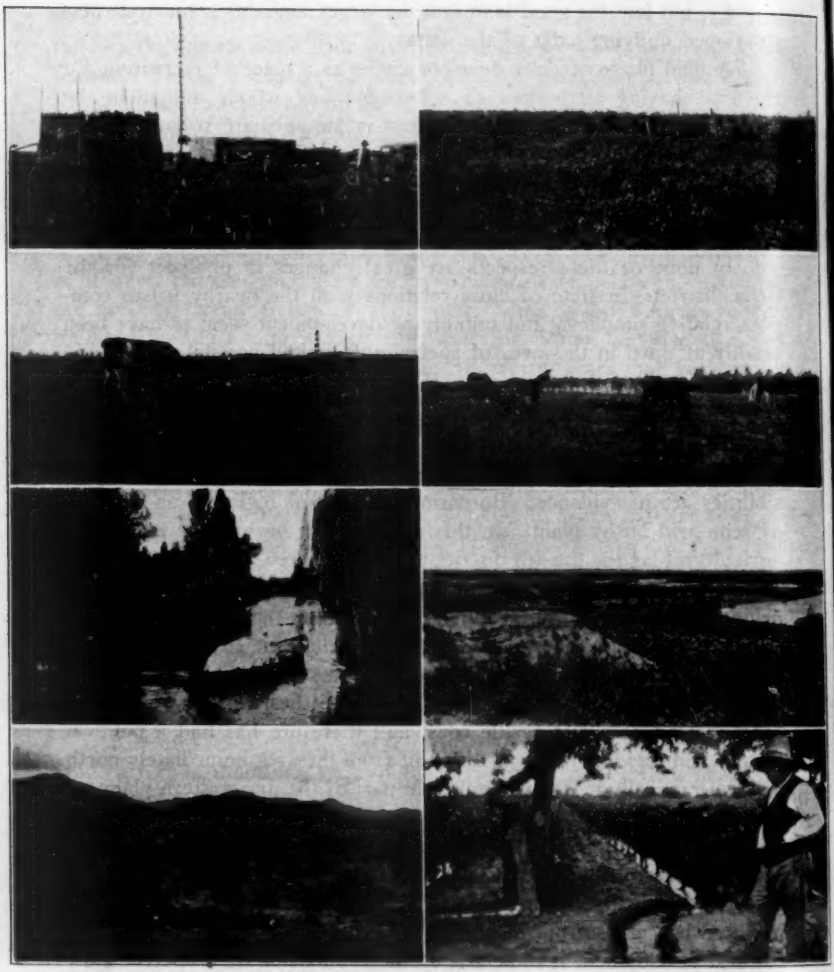

Fig. 13. Farmstead of the Chacra Zavalia. The house is in the background, the corn crib and loading device to the left (fig. 3).

Fig. 14. Fields of alfalfa and corn on the Tambo Roldán (fig. 4).

Fig. 15. Natural grass pasture, Estancia Cabo Corrientes, looking eastward toward the lighthouse and seashore (fig. 6).

Fig. 16. Pedigreed mares in planted pasture, Estancia Chapadmalal (fig. 7).

Fig. 17. Arroyo Carapachay, a minor channel of the Rio Paraná looking eastward from the dock of Isla Scarsi (fig. 8). The boat contains a load of delta produce.

Figs. 18, 19, 20. See page 421.

The Estancia Jones has an area of 32,000 acres with a river frontage of 4 miles (fig. 10). Inland from the river the property includes a square mile of swampy pitted floodplain, 8 square miles of low terrace, a strip of valley bluff 80 feet high, and above this 40 square miles of almost flat plain. Terrace, bluff, and upland all are occupied by dry bush vegetation. A large proportion of the bushes are useless, but some have leaves and some berries edible for animals, and there is a little bunch grass, green after rain.

The estancia has 2000 sheep, 1 to 16 acres. Occasionally there have been three or four times as many in unusually moist years, but recently there have been dry years. The average annual rainfall is 10 inches with large variations from the average. The sheep graze in the upland when there is available pasturage there, ordinarily in the cool winter season. In dry periods, generally in summer and sometimes all year, they are confined to the valley where there is slightly more vegetation.

Improvements include a fence around the property, and two inside dividing fences, a well 100 feet deep with windmill and tank in the upland and two shallower wells in the valley, two houses at the lower edge of the terrace for the Argentine brothers owning the establishment, and at one of the houses a corral and a shed for shearing and wool storage.

Wool is the chief product. The sheep are sheared twice a year, the unwashed clip is bagged and taken by truck to the railway at Choele Choel station 15 miles away. Sheep are sold at irregular times, some fat ones when pasture is unusually good and some thin ones when the pasture is too poor to sustain them. Sheep for shipment are driven to the next station, 12 miles beyond Choele Choel, loading pens being provided only at every other station, presumably on account of the sheeps' ability to walk long distances.

The estancia is not very prosperous and in a series of dry years seems almost worthless. Here multiformity and changeability of land occupancy are unheard of under the limitations of scanty opportunity. The size of the Estancia Jones is similar to that of Chapadmalal, each

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Fig. 18. View of north branch of the Rio Negro from the valley bluff, showing also the island of Choele Choel in the right background, the swampy floodplain in the center, terrace land and houses of the Estancia Jones in the left background, and a spur of the bluff in the left foreground (fig. 10).

Fig. 19. Dry plain at the foot of the Andes, close to the Mendoza oasis.

Fig. 20. Irrigation ditch in the Viña Puyzillon, looking northward from the road across the vineyard (fig. 12). At the right is the owner of the vineyard.

representing an old division for extensive grazing purposes, but unlike farms in the central region, the dry properties of the Choele Choel district all have remained large, and show no signs of changing to new forms of occupancy.

Even the advantage of estancias having unirrigable valley land seems too slight to be important. Northeastward across the plain from the Rio Negro to the edge of the central farming region there is very little variety in the pattern of occupancy.

Mendoza

Far west of the central region where the dry plain ends at the foot of the Andes is the 5th and last of the districts to be discussed (fig. 1). Here the plain is even drier than at Choele Choel (fig. 19), and is not organized in a pattern of fenced and functioning estancias. But streams from the high Andes, particularly the Rio Mendoza, here breaking from the mountains provide water for an oasis much larger than the island of Choele Choel (fig. 11).

The pattern of land division suggests the sharply restricted form of the area reached by water from the river, and the intricate dissection of this area into small functional units which are irregular because of a long history of unsystematic development.

One of the very small units is the Viña Puyzillon in the midst of the oasis (fig. 12). Water from the chief diversion dam of the Rio Mendoza reaches it by way of a main canal and secondary canals by which finally its proportionate share is delivered to the little vineyard (fig. 20). The vines are irrigated every two weeks during the latter part of the growing period, and are fondly cared for by the owner during the rest of the year, with very little hired assistance for pruning, tying, cultivating, and fertilizing. The owner is a French immigrant who came as a laborer to the newly planted vineyard 36 years ago.

The property has an area of 11 acres sloping gently northeast, all of fertile silt soil, occupied by French wine grapes of one variety. The rows extend approximately north and south, as is customary in the district, probably in deference to prevailing winds.

Near the house is a patch of corn. Some vegetables for family supply are grown between the vines, and a few fruit trees grow along the north side of the vineyard road and the south boundary of the property, where they do not shade any of the vines.

The only building is the dwelling house, a well-built villa in a corner of the vineyard close to the public road. The establishment is too small to have its own wine press and the grapes are sold when

gathered, being hauled directly to a commercial wine *bodega*. The harvest is a concentrated effort requiring extra hired labor—fifteen people for ten days.

In the Mendoza district many vineyards are larger than the Viña Puyzillon and some produce other kinds of grapes, table grapes as well as wine. Vineyards are not the only kind of farm enterprise but wine is the leading interest and the Viña Puyzillon a typical small establishment, a final example of simple and stable development in a district of special and limited possibilities, a last peripheral item in the Argentine pattern of terrene occupancy.

THE RESPONSIBILITY OF ENVIRONMENTAL AS COMPARED WITH HUMAN FACTORS IN THE DECLINE OF IBERIA

BY

W. O. BLANCHARD

University of Illinois, Urbana

Weak Nations.—Spain and Portugal are the sick nations of western Europe. Judged by the usual criteria of material and intellectual achievement they fail to measure up to the standards of their neighbors. They are, indeed, more like outliers of eastern and southeastern Europe.

Former Importance.—Yet it has not always been so. There is evidence that shortly after the beginning of the Christian era there were, perhaps three times as many people living in Spain as are there now. Under the Moslems it became probably the most enlightened and highly civilized country of Europe. Cordoba and Zaragossa were then famous seats of learning with large libraries to which scholars flocked from all parts of the continent. Agriculture flourished under the stimulus of an elaborate irrigation system built by a people who had been bred in the desert. Likewise industry and trade prospered. "Cordovan leather" and "Toledo steel" were household terms, everywhere synonyms for superior quality. Even in the late sixteenth century both Spain and Portugal were counted among the world's foremost nations. They were in the vanguard of discovery, exploration, conquest, and settlement of the new lands, and the Spanish Empire was one of the largest ever gathered under a single flag. Yet today no one even by courtesy would rate either Spain or Portugal higher than third or fourth class nations.

The Problem.—Has there been an actual decline, or is it a case of stagnation which has allowed other countries to forge ahead? Wherein lies the responsibility for this tremendous change?

Important Factors.—Of the various factors which have strongly influenced the development of Iberia the more important can be grouped under four general heads. They are (1) climate, (2) topography, (3) natural resources, and (4) people.

The Climate.—There is no doubt but that the climate of Spain is a trying one. Especially is its adverse influence felt in the deficiency of moisture. Approximately two-thirds of the penninsula is too dry

for ordinary cultivated annuals, and large areas can be best used only for pasturage, for dry farming, or for drought-resistant crops. This is a serious handicap for a country so predominantly agricultural.

Topography.—Topography also adds serious restrictions to both agriculture and transportation. About four-fifths of the peninsula is made up of the meseta, an old plateau block, averaging almost one-half mile in height. Its approaches are abrupt, and its surface is interrupted by deep gorges, and by mountain ridges. The rivers sunk deeply in the plateau are for the most part unsuited for navigation and of limited use for irrigation. No valley highway provides an easy route entirely across the peninsula in any direction. Furthermore, a regular coastline and the commercial isolation of the peninsula by the Pyrenees at the north and the Sahara at the south minimizes the possibility of through routes in any direction. Thus the population is concentrated mainly about the margins with wide stretches of sparsely inhabited broken country in the center. The problems of railway construction, maintenance and traffic, are difficult. France with about the same area, has three times the railway mileage with five times the railway tonnage, and in addition has 7,500 miles of navigable rivers and canals. In proportion to area, it is estimated that on the average to traverse the distance between two places in Spain requires a railway mileage twice the horizontal air line distance. Likewise the limitations upon agricultural development are almost as serious.

Aridity and rough topography have then, severely handicapped both agriculture and transportation. Yet rocky Italy with slightly less arable land supports about twice as many people as does Spain. Furthermore, only about half of the arid land of Spain capable of irrigation is at present being watered. Until recently the general system of farming in arid Spain has been to crop only one-third of the land each year, leaving two-thirds fallow to recuperate and to store the scanty rainfall. The Spanish peasant is said to "scratch his soil with a Roman plow" drawn by oxen. The sickle and scythe are common harvest tools. Almost every village has a threshing floor and 80 per cent of the threshing is still done by use of the flail or by treading out the grain by oxen or donkeys and then winnowing in the wind. Labor is cheap, unskilled in the use of machinery and generally inefficient. The use of fertilizers and agricultural machinery has been largely lacking.

With the coming of competition in the production of cheap grain from the New World, Denmark transformed its agriculture from grain growing to an animal industry. This latter not only provided higher priced products but furnished the fertilizers for the rehabilitation of a worn out soil. Spain's reaction to the same stimulus has taken the form

of high tariff walls on grain imports and she continues to grow wheat and barley with yields the smallest of any important country of Europe outside of Russia and the Balkans. Likewise she remains one of the lowest countries of Europe in animals per square mile or per capita.

One of the greatest single factors in retarding the economic and social development of the country is the poor land system. In the densely populated humid northwest, in certain sections, the land has been divided up to a fantastic degree and the price is most exhorbitant. There are holdings whose total areas are 130 and 430 square yards made up of bits, 7, 5, and even 2½ square yards each. These tiny patches are inevitably scattered, an owner possessing and farming 4 to 50 parcels. In the vicinity of Vigo isolated holdings of 35, 25, or even 12 square yards are common and 2 acres in one plot owned by one man is considered large.

But far more serious is the system of large holdings in the south, especially in Andalusia. In the province of Seville, for example, more than 2.5 million acres belong to the crown or nobility. More than 1,350,000 acres or 41 per cent of the entire Province is given over to pasturing fighting bulls, land much of which is capable of raising valuable cereal, fruit, or vegetable crops. One proprietor here owns 37,000 acres of arable land and in one municipality (Utrera) 30 individuals own an average of about 3,750 acres each, one of the farms embracing 62,500 acres, with several of 45,000 acres. It is not unusual to find, in districts containing more than 1,000 families living by farming, that 5 or 6 individuals own all of the land. Spain has about the same area as has Germany yet the latter has practically twice as many land owners.

In the absence of up-to-date figures on the size of holdings for all of Spain, we may take the average for the third of the country which has been recently reassessed. This shows that of the land owners paying a land tax, 82 per cent have daily incomes from that land of less than 1 peseta (16c), and must hire out as day laborers at low wages to eke out a living.[1] And this is in a country predominantly agricultural. As a consequence the great mass of peasants is steeped in misery and poverty[2] and the government has done little to remedy the evil.

Lag in Industry.—As in its agriculture so in its industrial development Spain has lagged. It possesses about the same amount of water power as does Italy, but has actually developed less than one-half as much. Besides, it possesses a considerable variety of mineral ores in-

[1] 847,548 owners out of a total of 1,026,412 covered in this survey.
[2] The per capita income in Spain in 1919 was estimated at $54.00; in Italy, $112.00 or more than twice as much.—Com. Mo. Dec. 1922.

cluding a small amount of coal, considerable deposits of iron ore, and fair resources of copper, lead, zinc, and mercury. Yet exploitation of these has been slow and has in many cases been left largely to foreign capital and enterprise, so that the profits of their refining and utilization have gone abroad. There have been wide gaps in the economic scheme so that even where raw materials were present, they were unused or else exported and then reimported in manufactured form. Thus in 1923 she imported 181,000 tons of phosphate, yet millions of tons lie within Spain untouched. She has regularly imported sulfur, but exported millions of tons of pyrite. She is one of the world's leading citrus fruit and wine producers, yet in 1922 she imported some 365 tons of citric and tartaric acid, exporting the raw materials. Only since the World War has there been a vigorous attempt to stimulate industrial development.

Inefficient Governments.—In the instability of their governments, both Spain and Portugal recall Balkan conditions. The Spanish monarchy now overthrown represented an outworn system suited for the 16th century. So frequent have been the cabinet changes that constructive work has been impossible. Thus between 1902 and 1923 there were 33 different ministers or an average of one every 7½ months.

Waste, corruption and inefficiency has characterized the governmental machinery for decades. Vast sums were used in the conquest of Morocco. A great army of civil service employees far beyond the needs of the country has been a heavy drain on the treasury. Deficits in the annual budget have been an annual recurrence for many years, and have had to be made up by loans resulting in depreciation of the currency and mounting interest costs. The system of taxation is antiquated and unjust. The minister of agriculture estimated a few years ago that even in Madrid province more than half of the taxable land escaped assessment.

Gross neglect of educational needs is amply evidenced by the fact that more than one-half of the population of Spain is illiterate.[3] One-fourth of the young are educated by the State; one-fourth by the Church. There are as many priests, and almost twice as many monks and nuns, as there are teachers in the entire State staff. But 3 per cent of the national expenditures was devoted to education in 1930, the service of the debt and the military and naval program absorbing the great bulk of the national revenues. The proportion of the national expenditures devoted to education is the smallest of any progressive country.[4]

[3] Of those over six years of age 54 per cent are estimated to be unable to read or write. This is five or six times the proportion in France.
[4] The London Times, Aug. 10, 1926.

Lack of popular support has forced the monarchy to ally itself with the army. The latter in turn has taken advantage of the situation and, on occasion, has usurped the civil authority. In spite of the natural isolation of Spain with the protection afforded by the Pyrenees, the expenditures for military and naval purposes is vastly disproportionate. Spain has one officer for every ten soldiers, a proportion double that in France.

The Church in Spain has long aligned itself alongside of a reactionary and autocratic government. It has used its great power to repress freedom of thought and the expression of independent opinion. With few exceptions it has pursued a narrow, intolerant policy, and "its educational system has been antiquated and thoroughly bad."[5]

In general, then, it seems to the writer that the decline of Spain has been a real one and that the major responsibility rests upon the people. The environment is a difficult one, but the inhabitants have not set themselves seriously to the task of adapting themselves to it; of employing modern knowledge and inventions for utilizing their resources as they might have. The very fact that its former population was in this same setting, once much further advanced, and the fact that a neighbor such as Italy with no better resources, has progressed much farther, and lastly the fact that Catalonia is an exception to the general decadence of Spain, seems to furnish ample proof of the human responsibility. The World War forced action, and there are many signs of an awakening. As this is being written, news comes that the monarchy is being overthrown. It will be interesting to see whether or not there may be a rejuvenation which may lift the country out of its slough of despair.

[5] S. de Madariaga, Spain, Chas. Scribner's Sons, N. Y., 1930.

ENVIRONMENTAL ADJUSTMENTS IN THE VALLEY OF THE LOWER RHONE

BY

ELIZABETH ERB WARD

Northwestern University, Evanston.

In southern France lies an area which plays an important rôle in the industry and commerce of the country and which presents an interesting example of man's adjustment to and capitalization of his environment. It is roughly triangular in shape with Valence at its vertex and the Mediterranean Sea its base, the Cevennes Escarpment of the Massif Central on its west, the Pre-Alps on its east, and the mighty Rhone River cutting through it from north to south.

At the southern edge lies Marseille, the second city of France and the country's leading port. It was here that a trade began as early as 600 B. C. which has risen and fallen with political tides but which has steadily grown until in modern times it bears every evidence of permanence. The Rhone Valley was known to Phoenician traders before 600 B. C. and doubtless the Greek mariners who founded Massalia, now Marseille, were not able to do so without some conflict with the earlier settlers. The Romans, eager to gain a foothold in Gaul, formed an alliance with the inhabitants of Massalia whereby they offered protection against native raids; such protection necessitated the landing of an army on the left bank of the Rhone. Roman rule continued for four centuries.

The history of civilization in Mediterranean lands has been concentration, expansion, collapse. Concentration meant adaptation to local conditions of climate, soil, and topography. Expansion followed the accumulation of wealth and power. Barriers of relief prevented expansion by land, but there remained the entire Mediterranean, almost any shore of which furnished a new area similar in character to the homeland. And Phoenicians, Greeks, and Romans had the advantage of dealing with a distinct climate, definitely limited in its distribution. Collapse came about, as one author states, "because of the impossibility of checking divergent evolution at the periphery."

Climate was the foremost environmental factor in the settlement of the Lower Rhone Valley. Except around the Mediterranean Sea, areas with Mediterranean climate are small and have not been favorable to

the development of civilization. But Mediterranean lands possess a strikingly uniform climate and it is this fact which has a significant bearing upon the migration of Mediterranean peoples. Here are groups of people who have exhausted their immediate environment; a short sea journey will bring them to an undeveloped area very much like home. The Romans themselves never went beyond the climatic barrier—they ruled the upper valley but never occupied it.

Physically, three subdivisions of the Lower Rhone Valley may be recognized, (1) the alluvial plains of Languedoc west of the Rhone, which produce one-third of the wine of France, (2) a part of Provence which lies east of the Rhone, and (3) the Delta between (1) and (2) which is flat and swampy in places and sandy, dusty, and barren in others. East of the Rhone lies the dry platform of La Crau, composed of gravels brought down by Durance River. West of the Rhone lies the swampy, uninhabited, unhealthful area of Camarque, a deltaic island formed by the silting up of the lagoons and salt marshes along the shore.

Marseille is located in Provence. It was founded nearest the Rhone where the advantages of the Rhone existed, but where the disadvantages of the delta were not felt. It is situated on the Golfe du Lion which is open to the west; to the east it is bounded by an amphitheatre of hills. The city itself is on undulating ground.

The question naturally arises—why has Marseille remained a vital trading center while other cities nearby rose and sank into oblivion? It suffered many vicissitudes as a result of political and clerical warfare. The Crusades temporarily increased its trade, for it was a convenient place to outfit an expedition, but its chief trade was with ports on the Mediterranean and in the East. During the Middle Ages, Pisa, Venice, and Genoa offered keen competition, and the trade of Marseille declined. Discoveries at the end of the fifteenth century caused trade to face west instead of east, and trade with the East went by sea around the Cape.

The opening of the Suez Canal in 1869 began a new era of commerce for ports on the Mediterranean. Before its construction there was no direct water communication between the Mediterranean and the Red Sea but after its completion Cape traffic was diverted through it and now mail boats from London to India and Australia call at Marseille.

The extension of French influence in North Africa has been of great importance. There is a constant effort on the part of the French to develop French Equatorial Africa with its wealth of resources and

the construction of the Transsaharan Railway will aid greatly in the growth of trade with Europe.

In 1902 a canal was built connecting Marseille with the Rhone at Arles. It makes of Marseille a river as well as a sea port, and, in a measure, surmounts the difficulties entailed by the enormous amounts of material deposited by the Rhone at its mouths.

But the chief environmental factor to which Marseille owes its present importance is its location at the southern end of the corridor of the Rhone Valley. This natural gateway is the great historical highway of France, connects the Mediterranean with the northwest of Europe, and serves as a passageway for commerce. Furthermore, there are gaps in the valley walls which enable a branching out from the main route.

The industries of the Lower Rhone Valley are dependent upon the natural factors of soil and climate. The cultivation of the vine on the fertile alluvial plains of Languedoc has already been mentioned. The olive tree with its small, hard, and varnished leaves is protected against evaporation. From the olives comes the oil needed in the large soap manufactories and oil refineries of Marseille and Montpellier, and in the candle making of the latter city. Tobacco thrives in the valley of the Isère where it is protected from the mistral but its quality is inferior. The raw products used in the textile industry which centers about Lyons are grown in the vicinity of Avignon. It was the successful cultivation of the mulberry in this region which gave a start to the silk industry for which France is noted, although today most of the raw material is imported. Iron and steel manufactures are produced at Alais which is located near coal and iron deposits. Bauxite, from which aluminum is manufactured, is mined near les Baux from which it takes its name, and lignite from the region about Marseille is used in the industries of that city. The salt marshes of Etang de Berre are important sources of sea salt.

The length of this paper does not permit further details about the natural resources and industries of the Lower Rhone Valley as a whole. Since the pivot of trade for the area is Marseille, it seems not out of order to describe the port whose modern aspect presents such a striking contrast to its appearance as a trading center of the Middle Ages.

In the first half of the nineteenth century, the port of Marseille consisted of a narrow embayment now called the "Vieux Port." Here boats anchored four deep and were loaded and unloaded by tenders. No provision was made for the supervision and protection of merchandise. Small rooms on ground floors of houses in the vicinity of the port—the number has been estimated at about 1,200—served as ware-

houses. A private company organized in 1856 was in a large measure responsible for the improvement of the port. Today Marseille boasts of modern port facilities with adequate machinery, warehouses, and a capacity for receiving the largest ocean-going vessels.

A concession was granted to the company in 1856 for a term of ninety-nine years from January 1, 1864, the date of the beginning of operations. In order to begin its work as soon as possible after organization, the company purchased land from the city of Marseille on which it conducted its activities until the lands granted by the concession were ready. The city soon realized that the success of the company's efforts meant increased trade and gradually the port was enlarged to its present proportions. That portion not controlled by the company is under the jurisdiction of the Chamber of Commerce of Marseille.

The water area of the docks is approximately 525 acres; the length of quays about 15 miles, and the total area of quays about 267 acres. Warehouses cover more than 100 acres. Improvements under construction or decided upon include enlargement of some of the docks, elongation of the breakwater for better protection against the sea, and reclamation of marshy lands for the use of the port. Projects include three new dry docks, an oil dock, and rearrangement of the general plan of all the docks so that there will be four cells. At present there are only two entrances, one for the Joliette dock, the other for all the other docks through the north outer port. The plan is to have an entrance into each of the four cells.

The equipment includes warehouses with a total capacity of more than 300,000 tons, 172 electric and hydraulic cranes, seven dry docks, a grain elevator which has facilitated the handling of cereals of which the imports are steadily increasing, and a refrigerating warehouse. The docks are provided with 58.5 kilometers of railway tracks.

The canal which connects Marseille with the Rhone has already been referred to. The most interesting feature of this canal is the Rove Tunnel which is cut through limestone for a length of 4.5 miles. It is 72 feet wide, of which 60 are for the canal itself, and along each side of the canal is a foot passage 6 feet wide. The height is 50 feet. The depth of the water in the canal is 13 feet. The volume of material excavated was 2,500,000 cubic meters. The tunnel was begun in 1911 and opened in 1927. It permits the passage of barges carrying from 1,200 to 1,500 tons and even more. It shortens the distance between Marseille and l'Etang de Berre to 18 kilometers and the later really becomes an auxiliary of the port of Marseille.

The canal from Port-de-Bouc to Martigues is the outer port of l'Etang de Berre. The total length of the quays is 7½ miles; the area is

about one square mile. On the north side are oil and soap works. Caronte is equipped for unloading and serves as a storage place for the coal of the Paris-Lyons-Mediterranean Railway (480,000 tons in 1928).

The opening of l'Etang de Berre to maritime navigation was decided during the war by the Chamber of Commerce. It has an area of about 60 square miles. Ships with a tonnage of from 8,000 to 10,000 can be admitted.

Summary

Early settlers remained in the Valley of the Lower Rhone because there they found a climate to which they were accustomed; the physical environment of the site of Marseille endowed it with advantages superior to those of any other point along the Mediterranean near the Rhone River; and colonization spread into the valley where the soil was fertile and agriculture could be carried on to supplement trading. Marseille persisted primarily because of its position with reference to the Rhone corridor. It owes its present position not only to events outside its control, such as the opening of the Suez Canal and the conquest of French Equatorial Africa, but also to its own progressive conquest of environmental difficulties.

GEOGRAPHICAL LOCATION AS A CONTROL IN THE NEW ENGLAND COTTON MANUFACTURING INDUSTRY

BY

J. HERBERT BURGY

University of Illinois, Urbana.

(Introduced by W. O. BLANCHARD)

Cotton manufacturing has been a major industrial adjustment in New England for seven score years. At the present time its prominence locally is still undisputed, but a new industrial area in the Southeastern States has wrested leadership from the older region in the nation's manufacture of these textiles. In 1925 the manufacture of cotton goods was the most important industry, accounting for 10 per cent of the total value of New England manufactures [1]. A study of the regional industries according to value added by manufacture in that same year again reveals the fact that cotton manufacturing is in first place with 9 per cent to its credit [2]. Artman, of the Bureau of Foreign and Domestic Commerce, makes the statement that 52½ per cent of New England's income from textile manufacture is derived from the cotton industry [3].

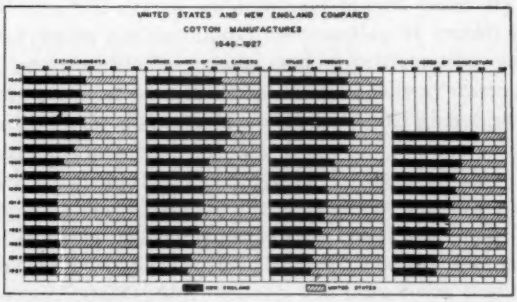

FIG. 1.

A graphical representation shows clearly the relative position of New England in American cotton manufacturing (fig. 1) [4]. All indices denoting textile prominence reveal the declining importance of this activity in the older industrial region. The number of active

spindle hours (fig. 2) [5] is the best index to use in judging the output of a region, and as can be readily seen, the divergence between northern and southern States has been rapidly increasing. The cotton-growing states took the lead in value of products manufactured in 1923; in the number of active cotton spindles in 1925.

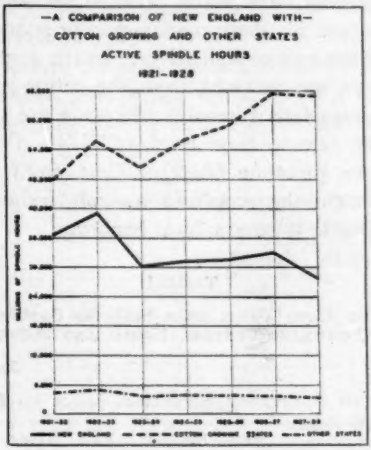

FIG. 2.

One of the principal geographic factors upon which New England cotton manufacturing depends is *location;* but its operation is frequently obscured by current economic conditions.

The supplies of raw cotton and bituminous coal used in New England cotton mills are extra-regional, originating for the most part south of the Mason-Dixon Line. It would seem, now that the Southeast has emerged as the principal producer of cotton textiles, that the wide separation of factory from cotton and coal fields would be a severe handicap to New England cotton manufacturing. This, however, is not the case. The location of the greatest consuming centers on tidewater is an extremely important factor in the movement of these commodities, the influence of low water rates tending to minimize the greater geographical distance of the northern units from their sources of raw material. Three-fourths of the cotton consumed in the Carolinas, the leading textile states of the Southeast, comes from areas west of Mississippi River. This region is also the source of the largest supplies used by New England mills; however, the discrepancy in freight rates will naturally be less because of the increased distance in

haul. Several authorities on this subject have estimated variously the differential. One says that the difference on shipments from the trans-Mississippi regions to the two competing cotton manufacturing districts is less than one-half cent per pound; if the southern mills, however, are supplied from local sources, the difference may amount to two cents per pound [6]. Another makes this statement: "The freight rates on cotton from points west of the Mississippi to points in the three important Southern manufacturing states average from 60 to 90 per cent of the rate to Fall River. In the southern States many of the mill centers are removed from the cotton-growing areas and freight rates on intrastate shipments of cotton are sometimes as high as one-half of the rate to New England" [7]. The following table amplifies the above quotation [8, 9]. Thus, from the standpoint of raw cotton movement the economic control—freight rates—modifies what would seem to be a geographical handicap.

TABLE I

FREIGHT TARRIFFS ON RAW COTTON FROM SELECTED CONCENTRATION POINTS TO CONSUMING CENTERS, NORTH AND SOUTH

From	To	Rates (cts. per 100#) All-rail	Rail-Water
Memphis	New Bedford, Fall River and Providence	120½	
Memphis	Charlotte, N. C.	89½	
Galveston and New Orleans	New Bedford, Fall River and Providence	123	55½
Galveston and New Orleans	Charlotte, N. C.	100½	
Montgomery, Ala.	Huntsville, Ala.	66	

Transportation charges on tidewater coal delivered alongside in New Bedford average $4.07, the rail charge alone from the mine to the southern port being $2.52, an amount which is but slightly below the total transportation cost from mine to southern factory. The average transportation cost per ton on coal from five southern coal fields to Charlotte, N. C., is $3.10; to Spartanburg, S. C., $2.71 [10]. There is no doubt but that New England mills and public utility companies using southern coal necessarily pay higher prices for fuel than similar units in the South. The relatively small part which such charges represent in the total cost of manufacturing—approximately 5 per cent [11]—makes this factor unimportant at the present time. Accessibility to deep-water transportation, however, operates and has operated ever since 1845, in effecting mill economy. Inland mills pay on the average about $1.25 more per ton than those located on tidewater [12].

One feature of New England's location which all manufacturers recognize as being exceedingly valuable in this day of "hand-to-mouth" buying and specialized and styled products, is proximity to New York. Excellent rail and water connections with that city, the greatest primary market for finished goods in the country and the center from which style trends emanate, facilitates the distribution of New England products which are to be consumed at home and abroad. Over-night boat service from Boston and the South Shore points predominates as a means of transporting the final product to Manhattan. The convenient location of the wharves within a quarter of a mile of the Worth Street section, the textile trading center of the metropolis, is a decided

TABLE II

RATES ON COTTON-PIECE GOODS—NEW ENGLAND AND POINTS TO NEW YORK.

Point of Shipment	Rates (in cents per 100 lbs.) All-rail	All-water	Rail-water
Boston	51	36½	
New Bedford, Fall River and Providence	51	24	
Lowell	53½		39½
Manchester, N. H.	55		39½

RATES ON COTTON-PIECE GOODS—SOUTHERN CENTERS TO NEW YORK AND BOSTON

Point of Shipment	Rates (in cents per 100 lbs.) All-rail	Rail-water
Atlanta, Ga.	87	84
Greenville, S. C. Spartanburg, S. C. Gastonia, N. C. Charlotte, N. C.	81	77
Greensboro, N. C.	74	69
Danville, Va.	80	56

advantage in moving the goods as the railway freight stations are located farther uptown. A comparison of all-rail, all-water, and rail-water rates between various New England points and New York explains why mill men stress the importance of tidewater location in this connection (Table II) [13, 14].

The greater geographical distance between southern mill centers and New York with the resultant higher freight rates on piece goods, tends to equalize the slight advantage which these points have over New England relative to the movement of raw cotton. If one compares the freight rates shown in Table II, the 400- to 500-mile greater haul is evident. New England manufacturers agree that proximity to markets is more important than proximity to raw materials inasmuch as the time element in placing goods on the market at propitious intervals is capitalized, in some instances, according to one authority as

high as one cent per yard [15]. It should be said in this connection, however, that New England centers enjoy no advantages over southeastern points so far as tariffs to Chicago, St. Louis, Kansas City, Memphis, and Atlanta are concerned [16].

The fact that New England is the most important finishing center of cotton goods in this country is significant in making for ease and economy in the transfer of textiles from mill to finishing plant and market. Figure 3 shows the distribution of finishing plants in 1928 [17]. Their greatest density in the Providence region, the locality having the greatest number of spindles (fig 4), and the proximity of this area to New York City puts emphasis on the *location* factor. The need for this kindred industry and the impetus it received in the early days of cotton manufacturing are apparent today, consequently a consideration of New England's location necessarily involves the advantage of this man-made facility.

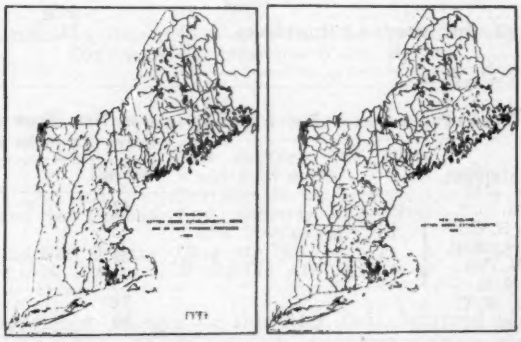

FIG. 3. *(Left)* New England cotton goods establishments doing one or more finishing processes in 1928.
FIG. 4. *(Right)* New England cotton goods establishments, 1928.

Approximately 75 per cent of the cotton goods manufactured in the Southeast is actually sent to New England for finishing. The location of the established finishing industry with its skilled labor, reputation, and economies operates in offsetting the longer haul necessitated by shipping the grey goods to northern leacheries and dye houses.

The superintendents of such establishments in New England are fully aware that increased quantities of southern products are being finished in the South—that the advantage possessed by allied textile industries of the North, purely from the standpoint of location, is being gradually nullified.

The several aspects of geographical location as they apply to the movements of raw materials and finished products all operate directly, yet their value to the industry in the present critical period of readjustment is very largely lost sight of, with but one exception: the nearness of New England mills to New York City. This receives unusual attention by local manufacturers and is an outstanding geographical advantage which enables the region to compete for a considerable amount of domestic trade.

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PAPERS IN MEDICINE AND PUBLIC HEALTH

EXTRACT FROM THE REPORT OF THE SECTION CHAIRMAN

All eight papers on the program were presented at the meeting of the Medicine and Public Health Section but the following two were not presented for publication:

"Vitamin B Deficiency and Learning Ability," by Siegfried Maurer, and Loh Seng Tsai, University of Chicago.

"Sanitation and Conservation of the Waters of Illinois," by Harry F. Ferguson, State Department of Public Health and State Sanitary Water Board.

No chairman was elected for the following year*

(Signed) JOHN C. FRAZIER, *Chairman.*

*The Council appointed Harry F. Ferguson, State Department of Public Health, Springfield.

UNUSUAL LESIONS IN SWINE BRUCELLIASIS

BY

W. A. JAMES, FRANK THORP, JR. and ROBERT GRAHAM

Laboratory of Animal Pathology and Hygiene
University of Illinois, Urbana

The entire thesis of the paper can be stated briefly in three premises, with conclusions pertaining to an unusual or heretofore undescribed bone lesion in swine suffering from Brucelliasis (porcine infectious abortion).

1. Swine Brucelliasis (porcine infectious abortion) has been recognized as a spontaneous disease in hogs on Illinois farms over a period of approximately ten years. The initial infection in many herds coming to our attention is characterized by expulsion of immature litters. Infected herds, however, do not continue to abort. Many aborting sows (porcine infectious abortion) may not subsequently abort but carry their litters to maturity. Therefore, following the initial outbreak in herds, abortion may occur only rarely or not at all. The disease in such infected herds can be accurately determined only by the application of the agglutination test, or by bacteriologic examination of the tissues of infected animals.

2. The agglutination test for Brucelliasis when applied to the blood serum of several hundred breeding hogs on Illinois farms, without reference to the history of previous abortion, suggests that approximately five percent of the animals either have been infected, or harbored the infection at the time tested. Gross pathologic lesions of Brucelliasis in swine have rarely been recognized by the clinician. Infection of the reproductive organs of the male may be associated with orchitis and abscess formation in the testes. In the pregnant female, placentitis constitutes the outstanding gross pathological change, but this lesion is not specific.

3. In our observations bone lesions may be associated with Brucelliasis, in support of which the following data is presented. On a farm in McLean County, Illinois, where hogs have been raised for a period of 40 years, an increasing number of the breeding animals have in the last decade developed symptoms of lameness and stiffness (fig. 1). A clinical examination of the affected animals revealed distinct swellings of the articulations of the extremities (fig. 2). The other

animals suffering from difficult locomotion (stiffness, soreness, and lameness) failed to show clinical arthritic involvements. At autopsy, the pigs showing clinical arthritic involvements were found to suffer from pyogenic arthritis with an abundance of creamy, yellow pus in and distending the articular capsule (fig. 2). The bursa adjacent to the articulation were also involved, while the articular surfaces showed focal erosions. One other animal that displayed marked symptoms of lameness failed to reveal any involvement of the articulations at autopsy. An examination of the bones of the legs bisected longitudinally revealed multiple abscesses in the epiphysis of the long bones (fig. 3 and 4). The specificity of these suppurative

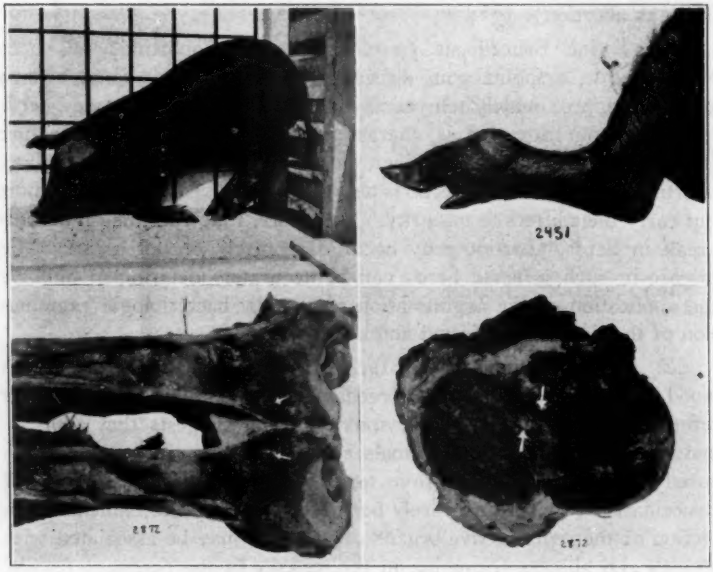

FIG. 1. *(Above, left)* A pig affected with a Brucella osteomyelitis. Note the enlargement of proximal extremity of the radius at the cubital articulation. The painful bone lesions prompt the animal to walk or rest on the knees with a portion of the weight supported by the head.

FIG. 2. *(Above, right)* A pig affected with Brucella arthritis. A metacarpo-phalangeal swelling was soft and fluctuated on palpation. Autopsy revealed a pyogenic arthritis with erosions of the articular cartilage.

FIG. 3. *(Below, left)* Longitudinal section of the left radius showing Brucella osteomyelitis (pig shown in Fig. 1). Note the necrotic foci (arrow points) in the epiphysis of radius. The articular cartilage of the cubital articulation is normal.

FIG. 4. *(Below, right)* Cross-section of the head of humerus (pig shown in Fig. 1). Note the multiple circumscribed abscesses in bone marrow.

osteomyelitic lesions was suggested by the positive serum agglutination reaction in dilution of 1 to 800 as well as by isolation of the porcine type of Brucella from the pus found in the bone lesions.

Conclusions: As a result of the above observation, it is apparent that arthritis and osteomyelitis in swine may cause marked symptoms of lameness and stiffness. These inflammatory pyogenic bone lesions with multiple necrotic foci in the epiphysis of the long bones harboring Brucella suis Traum suggests the possible significance of this bacterial infection in a new rôle, distinct from invasion of the reproductive organs.

RELATION OF THE DOG TO PUBLIC HEALTH

BY

MINAS JOANNIDES, M. S., M. D., F. A. C. S.

ASSOCIATE IN SURGERY, *College of Medicine*
University of Illinois, Chicago.

INTRODUCTION

Life is an endless struggle for existence. This existence involves our relationship to our fellow men both as units of a social whole and also as individuals of the animal kingdom. From the moment that we become conscious of ourselves until the moment that we are placed in our graves we struggle in our play, our work, and our hours of rest. All our actions turn in the direction of self preservation and the enjoyment of life. In our individual life we eat the flesh as well as the products of living beings so that we may not starve to death. In our business life we always try to compete with our neighbors and crowd them out of business in order that we may get most of the monetary reward. In our social and national life we have our ego which stands out in bold relief. Let the ego take the background and before long defeat must be acknowledged.

Life is a banquet. We live to eat. When our time comes, we serve ourselves as a meal for other living beings. We keep alive by eating plants or animals; they in turn eat other plants or animals and so on down to infinity. We may have scruples about eating human flesh but the flesh of certain animals that serve us for food purposes is no different in its chemical composition than that of our own. Vegetarians do not eat meat because among other reasons they assume that plants have no similarity to the animals. This is far from the truth because the plants do everything an animal does with perhaps the possible exception of moving about from one place to another. In this banquet where the strong eat the weak we must be on our guard at all times otherwise the enemy—human, bacterial, or physicochemical—will strike at a moment of unpreparedness. Unless we can fight our enemy, we necessarily must lose, and thus pass to the great beyond—the happy hunting ground of philosophers and theologians.

Struggle for existence is a natural phenomenon. We see it in all forms of life. From the lowest plants or animals to the most intricate and best developed forms of life this struggle for existence is

very evident. Even the plants that are lacking the power of locomotion show definite manifestations of this struggle. If we go to the forest, we will be impressed at once with the height attained by the trees. Growing tall is necessary if the forest trees would live. They must have exposure to the rays of the sun in order that they may manufacture food for themselves. By means of the process of photosynthesis the plants can utilize the chlorophyl in their leaves to manufacture food. In other words, the more leaves a tree has for exposure to the rays of the sun the greater the photosynthesis and the sturdier the tree. We have, therefore, a constant attempt by these trees to grow tall and allow more leaves to be exposed to the vital rays of the sun. Thus the trees that cannot reach the top become wilted and in due time dry up leaving more room for the sturdier ones. It is likewise with man. Man has to fight in order to readjust himself to his environment. Man is surrounded by disease germs at all times, and if he does not have a strong, healthy body, he will succumb and eventually die. Changes in the atmospheric conditions about us have a great deal to do with the length of our lives in this planet. Disease is fundamentally a reaction on the part of the body against a massive attack of a foe that is foreign to the body cells. Even though our bodies have the power of self repair, at times the repair is not complete with the result that such individuals have to carry on their daily routine by placing an added strain on some organ of the body.

Man is a composite living being, and is made up of billions of individual living cells each of them being a distinct unit. A certain number of cells take on special forms and functions, and thus go into the making of organs. By having a division of labor and assuming specialized functions the cells work to preserve themselves, their own kind, and finally the neighboring cells in the body. The cells have constant communication with their headquarters in the brain by means of the delicate telegraph system represented by the nervous system. The railroad system of the body by means of which necessaries are brought and waste products are taken away is well represented in the heart and the circulation of the blood. One can go on and find many analogies and similarities between the workings of our complex body and the social community in which we live as units. Thus in our body we have a coordinated action of millions of cells working in unison for the benefit of their own world—our body. It is so in nature. Cells go into the making of bodies. Individuals make up colonies, nations, or races, and all live in this very small unit of the universe, our mother earth.

Disease in most cases is preventable. If proper precautions are taken so that in addition to a healthy body we do not allow any disease producing germs to enter our bodies, we might have a chance to live to be as old as Methuselah. Preventive measures have increased our average age in this earth from thirty years to more than forty. There is no reason why we cannot increase this limit to a much higher level. Our contact with anything that is infected with disease germs will make us liable to the disease. Thus, exposure is a very important link in a chain that leads to disease and misery. If we break the chain of contact by knowing certain facts about prevention, we may become free from a good many diseases. Infectious disease is always carried from one individual to another. A person infected with a certain disease in coming in contact with others in the schools, in the trains, or in the theatres, becomes a public menace because he may spread the disease to hundreds of unsuspecting individuals. What is true of the human carrier is also true of our domestic pets that may carry parasites which produce disease to man. The dog comes in most intimate contact with man. It is the unusual thing not to find, in the dog's intestine, parasites that have been proved to produce disease in man. Though the dog is a true friend, as a result of carelessness of its master, he becomes an unwilling enemy—our friendly enemy.

The King of Domestic Animals

Before we discuss the ways and means by which the dog may carry diseases to man, it might, perhaps, be appropriate to study the relationship of dog to man. The lion is admittedly the king of the wild animals. No one will dispute the claim to this title for the dog if we limit our field to the domestic animals. Of all the domestic animals the dog has reached closer to the heart of man than any of its competitors. One may see cats or canaries in homes but most families that want to have a pet in their home prefer a dog. One may find many varieties of dogs depending on the personality of the owner. Thus the ladies of leisure are seen with their small and often weird looking pekingese, spaniels, or yorkshires. Some of these dogs may weigh only a few ounces, and make cute living toys for the fashionable women to carry around and thus attract the attention of the passer-by. For the big athletic boy, who would admire strength and good physique, a Saint Bernard, a mastiff, a greyhound, or a wolfhound would be an ideal companion. The hunter, on the other hand, would prefer a deerhound, a pointer, or a setter, while the average home owner that wants to have protection for his property would choose a bulldog in his backyard.

The dog has been a close associate of man, probably even from the most primitive stages of mankind. The more primitive the races of our day the closer is the contact between the dog and its master. To the Eskimo of today the dog is a very necessary part of his surroundings. The dog serves not only as a companion but also as a servant and a guardian. The Saint Bernard is famous for the services that he renders to those marooned in the snow covered mountains. The recent world war proved beyond any question of doubt that the dog is really of great service to man. In the average backyard, long before any one suspects the presence of an intruder, the dog gives the necessary warning with the usual bark. Be it a keen sense of smell, hearing, or sight, it is so acute that the dog perceives the presence of a friend or enemy very early.

The dog has many good qualities that help it get the name of king of the domestic animals. He is a companion and a guardian. No other domestic animal has those qualifications. The cow can only supply milk and meat. The pig supplies the pork. The hen and its relatives supply us with eggs and meat. The horse uses its strength to our advantage. Is there an animal around a household that can surpass the value of the dog? Of the other domestic animals that vie for honors the cat is the only other one. The cat, however, is a parasite. She likes to be praised and petted but revolts and scratches when punished. On the contrary, the dog not only takes punishment without much complaint but wags its tail obediently. The courage that the dog has shown never has been equalled by any other domestic animal. A dog would gladly dare swim any turbulent stream to lend a helping hand to its master. The dog is appreciative. Do a good deed for a dog and he will remember you for months and years afterwards. Kick a dog for malice and months later he will growl at you from a distance as great as a half or even a whole block. Be good to a dog and he will sacrifice his own life to save yours. In general the dog has numerous characteristics that are human. In addition to these he has courage, he is obedient, and perseverant. Those are all kingly qualities, and the dog, who always has them all, must be classified as the king of the domestic animals.

Our Friendly Enemy

The dog is by far man's best friend. A man may be forsaken by his family, his friends and enemies, but never by a dog. Once a dog becomes attached to a person the animals sticks to the master until the end. All the adjectives that signify a noble character may well be applied to the dog.

There are numerous incidents that are spoken of to portray the courage and self sacrifice of the dog. Is it any wonder that we regard the animal as our best friend? Next to children we like the dogs best of all. Some people prefer the dog even to children. The dog does not discriminate. Once adopted as a pet the dog will stay with the master regardless of sex, age, color of the skin, or social status. It makes no difference to a dog whether the master is a king or a tramp. He would just as soon travel on foot with his tramp master as to travel de luxe in a private train of the king and his retinue. Be kind to the dog and he will be faithful to you until the end.

The dog is not selfish. As long as the dog is given enough food and a comfortable place to sleep, he is satisfied. He would even tolerate rough handling when it is justifiable. A story is often related of an experience of Napoleon the Great. "Amidst the silence of a beautiful moonlit night a dog leaping suddenly from beneath the clothes of its dead master rushed upon us and returned to his hiding place howling piteously. He alternately licked his master's hand and ran towards us. I voluntarily stopped," relates Napoleon "to contemplate the scene. This man, thought I, has his friends in the camp but he is forsaken by all except his dog." No doubt the dog was so unselfish that he made the great sacrifice of remaining close to his master's body until he died. No parallel is found in the animal world except as it refers to a relation between the mother and the offspring. It is not at all surprising that man should care for the dog better than any other of the lower animals.

In spite of all the good things that we can say about the dog, the latter is instrumental in spreading certain diseases from himself to the master or from one individual to another. On account of the great love that we all have for the animal we give the dog so many privileges that at times he becomes dangerous. There are certain restrictions that must necessarily be imposed upon the dog, otherwise he becomes an unwilling carrier of disease. If not restricted, the dog becomes a potential enemy—our friendly enemy.

The Dog as a Carrier of Disease

A carrier of disease is any one who is instrumental in the transmission of a disease. There are two types of such carriers. In the first class belong those who act as carriers during the course of an illness. Those suffering from pulmonary tuberculosis are a very good example of this type of transmission. A person afflicted with tuberculosis of the lungs may cough up millions of tubercle bacilli, and if not careful about the disposal of the sputum, he becomes a menace to

society by exposing all those about him to the disease. In the second class of carriers belong those individuals who carry certain pathogenic micro-organisms without the least discomfort or evidence of any physical disability. For example, a certain group of persons have a great tolerance for the germs of typhoid fever. If these persons work in any place where food products are being handled, they may very well act as a proper means of developing a typhoid fever epidemic. Such epidemics may frequently arise from a restaurant or a dairy plant.

The dog may be regarded as a carrier of both types. There are certain diseases such as rabies, tuberculosis, and some skin diseases that cause definite symptoms in the dog just as they do in man when the latter becomes infected. It is during the period of his illness that the dog may carry the disease to man. On the other hand, the dog may carry certain parasites and also the germs of practically all childhood diseases without showing any signs of illness. He thus becomes a mechanical carrier of disease. Let us now analyze how the dog becomes a disease carrier and therefore our friendly enemy.

Wanderlust in man and beast is an inherent quality for search of new surroundings and new experiences. Every man in his gradual mental evolution goes through a period during which he has an irresistible desire to get away from the ordinary surroundings. Charles Darwin in his Origin of Species states that "there is good reason to believe that slight changes in the conditions of life give vigor and fertility to all organic beings." Most of us experience exactly what Darwin states when we go on our summer vacations. When we return we feel so invigorated and anxious to get back to work that it takes several weeks or perhaps months before our work becomes a job again. The ever present instinct of always looking for terra incognita and new experiences varies in different people. This instinct may be developed to such a great degree that in some people, such as the gypsies or the hoboes, it modifies their mode of life to fit this peculiarity. The dog is more or less a hobo and likes to skip out whenever opportunity offers itself. In spite of the close domestication and care, the dog frequently finds his way out into the backyard or alley in search of new playmates or surroundings. During such expeditions the dog literally sticks his nose and paws in all possible garbage cans and dirt. He also mingles and plays with the children of the neighborhood regardless of their health or cleanliness. A sick child or one that is a carrier of a disease present in a brother or a sister hails the dog and plays with him. In his attempts to show appreciation the dog may come in very intimate contact with a carrier and thus on his return to the master's home he is no longer a

friend but an enemy, laden with germs of any childhood disease that might kill the youthful master.

Before we make any effort to describe the more serious diseases that the dog may carry, it might be appropriate to give a brief outline of the diseases and parasites that have been reported in the dog and also in man.

I. Rabies or hydrophobia.

II. Tuberculosis.

III. Mechanical Carrier of Childhood Diseases.

Measles, scarlet fever, diphtheria, poliomyelitis, whooping cough, chicken pox, mumps, pneumonia, and intestinal diseases of infectious origin.

IV. Intestinal Parasites.

A. Protozoa.

1. Entamoeba histolitica—causing dysentery.
2. Giardia or Lamblia intestinalis—causing enteritis and gangrene of the lung.
3. Trypanosomes—causing sleeping sickness.

B. Roundworms or Nematodes.

1. Toxascaris limbata.
2. Eustrongylus gigas or giant blood worm or giant kidney worm.
3. Trichinella spiralis—causing inflammation and abscesses of muscles.

C. Flukes or Trematodes.

1. Opisthorchis felineus.
2. Paragominus Kellicotti—a lung fluke.
3. Clonorchis sinensis.
4. Clonorchis endemicus.
5. Schistosoma japonicum.

D. Tapeworms or Cestodes.

1. Echinococcus Granulosus.
2. Coenurus cerebralis or the Gid.
3. Dipylidium caninun.
4. Dibothriocephalus latus.

V. Skin Parasites.

A. Lice and Fleas.

1. Trichodectes canis—a flea harboring one stage of dog tapeworms.
2. Pulex irritans.
3. Ctenocephalus canis.

B. Mange (scabies) parasite similar to, perhaps same as in scabies (seven year itch).
   1. Sarcoptic type.
      Follicular or demodectic type.

C. Ringworm.
   1. Trichophyton microsporum oospora.
   2. Eidamella.

D. Ticks.
   1. Dermacentor variabilis.
   2. Darmacentor venustus—carrier of organism that causes Rocky Mountain spotted fever.

VI. Arachnida.

A. Tongue worms or linguatula rhinaria.

It is evident from this outline that the dog is a definite factor in the transmission of diseases and must be thought of as such more seriously than was done in the past. It is also evident that these diseases are not easily recognized by the average person. It is necessary therefore to be on our guard always for possible infection from the dog. By following some simple rules it is very easy to make the dog perfectly harmless in the household.

Of the diseases carried by the dog the most serious is that of rabies or hydrophobia. It is an acute disease and kills its victim very promptly. Like tetanus, it can be prevented by prophylactic injections but when left to itself and developed in its full clinical form, it always kills. The frequency of this disease is in proportion with the strict observance of the local muzzling laws. Rabies is practically unknown in countries where the laws compel all dog owners to muzzle their dogs before they allow them in the streets. Thus in North Germany rabies is practically unknown because of the strict observance of the muzzling regulations. In England there was an average of about thirty deaths a year from hydrophobia until the enforcement of the muzzling law. Since then—1912 to 1926—no deaths from hydrophobia have been reported from England. In the United States where no one observes the existing muzzling regulations we still average about sixty deaths a year from hydrophobia. These deaths are absolutely uncalled for, and these people do not have to be sacrificed on the altar of the god of careless dog owners. The solution is perfectly evident. Muzzle all dogs when they are out in the streets and you will have no deaths from rabies.

The germ of rabies is present in the saliva of the dog. It finds its way into the human body through a scratch or a bite from the rabid

dog. Once the germ is introduced into the body, the patient or the susceptible animal will surely die unless given the innoculations that have been discovered by the great Frenchman Louis Pasteur. These prophylactic injections have been so well perfected that any physician now can give the treatment just as easily as the injections for the prevention of lockjaw.

In the dog the disease manifests itself in two forms namely, the furious and the dumb forms. The furious form corresponds to the stage of hyperexcitability in the human. The dog will gnaw on wood or clothing and has a strong desire to run away. He refuses the usual food, or takes it, holds it in the mouth for a moment and then drops it. He has a strong tendency to snap at everybody. It is during this stage that the dog is most dangerous. At first opportunity he will run out and bite everyone that he encounters. Soon the paralytic stage develops. This has a characteristic tendency to have paralysis develop in the dog's hind legs. During this stage the dog dies of heart failure. In the dumb type the stage of hyperexcitability is only very slight and promptly goes on to the paralytic stage and carries off the animal.

After the disease develops the only treatment that is given is to relieve the patient of the agony during the stage of excitability. Nothing so far has been successful in the cure of the disease after it has developed. In order then to save at least sixty human lives a year in the United States we must prevent infection by muzzling the dog. Moreover, if one is bitten by a dog that acts queerly that dog should be handed over to the proper authorities to watch the animal for typical symptoms or if necessary to sacrifice the animal in order to see if the Negri bodies are present in the brain. If there is any suspicion of rabies the prophylactic treatment should be instituted at once in order to save that human life. In Illinois we have a regulation forcing dog owners to take a dog to the pound or a dog hospital for a ten day observation when the animal bites someone. If the animal shows any suspicious signs of rabies, it is killed and the head is sent to the State Public Health Laboratory to determine the presence of Negri bodies. In the meantime the Pasteur treatment is begun on the patient.

Intestinal parasites may be easily transmitted from the dog to man. Intestinal parasites are of three different varieties. In accordance with their general shape they are classified as roundworms, tapeworms, and flukes. These worms vary in size from two millimeters to one and a half meters or more in length. Thus the echinococcus worm measures only 2.5 millimeters in length, while the giant kidney or blood worm (eustrongylus gigas) measures 1 to 1.5 meters in length. Both these are found in the dog and both are transmissible to man. Another

important characteristic of the intestinal parasites is the entire change of form and manner of living during various stages of the life cycle. These changes may be regarded as mutations if we may be permitted to use the term. One sees an entirely different individual under completely different surroundings and had it not been for the untiring efforts and studies of the zoölogists we would be blind to the fact that these variable forms are only different stages of the animal's life cycle.

Two distinct periods can be demonstrated in the life cycle of the echinococcus. The adult form is found in the intestine of the dog and certain other animals that do not have an intimate contact with man. The embryonic form is the one that is found in man and also certain domestic animals. The embryonic form manifests itself in the form of bladder-like cysts that may be lodged anywhere in the body but more especially in the liver and the lungs. Such cysts have also been found in the heart, the brain, the eye, the kidney, or underneath the skin. It is amazing how the parasitologist, like a Sherlock Holmes has traced the worm through the various pathways that it takes in its existence. In the dog's intestine the worm presents the following characteristics. It is a very small tapeworm and measures only 2.5 millimeters in length and 0.6 millimeter in breadth. The head measures about 0.7 millimeter in breadth and has four suckers and a double row of hooks of various dimensions. Generally there are thirty to fifty hooklets on the rostellum. The neck is very short, and the body consists of three or four subdivisions that are called proglottids. The terminal proglottid, when mature, contains four hundred to eight hundred eggs with their hexacanth embryos. Each egg or ovum measures thirty to forty thousandths of a millimeter and contains an embryo. Each terminal proglottid is liberated and with it are also liberated the hundreds of eggs now free to roam for new experiences and new surroundings. They find their way to the outside world in the feces of the dog. Some eggs remain clinging on to the dog's hairs, his paws, or his mouth. In more than one way they ultimately find their way into the mouth of man. Frequently a statement is made that typhoid fever is a connecting link between the feces of a patient suffering from typhoid fever and the gastro-intestinal tract of the next man who becomes ill with typhoid. This statement is equally true in echinococcus and also most of the intestinal parasites. Because the echinococcus spends its adult life in the intestine of the dog, the latter is referred to as the direct host in contradistinction to the term intermediate host in whose body the parasite spends its embryonic existence. One of the intermediate hosts of the echinococcus is man.

Let us now follow the worm from the dog to man. After the eggs reach the mouth of the host, they are easily swallowed and are lodged in the stomach. In four to five hours the gastric juice dissolves the membrane of the egg and thus liberates the living embryo. The latter now gets mixed in the food content of the stomach and passes down into the intestine. Here it attaches itself on to the mucosa of the intestine by means of its hooklets. The embryo now burrows its way into the wall of the intestine and, after reaching the capillaries, it enters the circulation and finds its way into the various distant parts of the body. It lodges most commonly in the liver and lung and develops into a cystic mass—the hydatid cyst. The body of the host now mobilizes its own defensive powers and tries to localize this cyst by building a thick wall around it. Thus if this wall is strong enough the hydatid may develop and stay there indefinitely or even die without producing much harm to the body. Frequently after its full development the hydatid cyst ruptures and liberates its contents that reach the dog and develop into adult worms. The hydatid cyst is made up of a thick laminated wall and an internal wall which serves as the germinating layer for the smaller or daughter cysts. Within these daughter cysts one sees the developing young scolex. In other words each daughter cyst represents an adult worm. In each hydatid cyst there may be as many as five hundred daughter cysts. The development of the scolex is very slow and requires five to six months before the worm reaches maturity. It is these daughter cysts that eventually find their way into the stomach of the dog, their wall is broken, and an adult worm finds itself in the intestine of the dog.

Echinococcus disease is most common in countries where the dog is in very intimate contact with man. Thus in Iceland, Australia, and Brazil the disease is most prevalent for obvious reasons. It is found in all parts of the world. In the United States there are as many as five hundred cases reported. This number, however, represents only a very small proportion of the actual number of cases in this country. Invariably the dog can be traced as the carrier of the disease.

Fortunately echinococcus disease yields to proper treatment and therefore is not as deadly as rabies. It is a preventable disease and must come under the control of the public health measures. Two routes are open for the prevention. First, contact with diseased dogs may become eradicated by curing the dog of the echinococcus. In the second place, we can limit the privileges of the house dog so that even if infected the dog will be harmless. The wisest procedure would be to eradicate the worm from the dog's intestine and also to limit the dog's privileges in the home so that there would be no possibility of infection.

Tuberculosis is less common in the dog than in man. In spite of this fact, however, the animal can easily act as a carrier of the disease. The dog carries tuberculosis primarily as a mechanical carrier. By coming in contact with someone who is suffering from tuberculosis, the dog can very easily carry the tubercle baccillus to someone who does not have the disease. Tuberculosis is a very common disease among human beings. Various observers, particularly Opie, have definitely shown that tuberculosis is practically a universal disease. Opie has found tubercles in the lungs of more than 95 per cent of his autopsies. In spite of the fact that tuberculosis is such a common disease, only a very small proportion of the people die from the disease. It is those people who are undernourished or have a low resistance that usually die from the disease. Children and people of old age are more likely to die from tuberculosis than the young adults. Tuberculosis in infancy almost invariably means death to the child. An infection with the tubercle bacillus may or may not mean the development of the disease. It is for this reason that in spite of the large proportion of infected individuals with tuberculosis only very few die of the disease.

The dog is in very intimate contact with his master's household. He is allowed to play with the children of the family and even to eat at the same table with his master. Frequently careless or over-loving masters will allow the dog to eat even from the same plate. By going around in the neighborhood the dog can pick up many germs one of which may be the tubercle bacillus. Frequently the dog lives in a household where there is a patient with active tuberculosis. In such a household the dog may easily come in contact with the tubercle baccilus and carry it mechanically to other individuals. Careless patients who cough up a certain amount of sputum and do not dispose of it in a way so as to make it harmless may easily become instrumental in producing a carrier out of the dog. In an ordinary amount of sputum it has been shown that one can find several billion tubercle baccili. If that sputum is not disposed of properly by expectorating into a paper napkin and then burning it, one can easily transfer the germs from one individual to another. Naturally a small amount of sputum which is loaded with billions of bacteria, when dried up will allow these germs to float in the air and eventually find a landing place in the lungs of the unsuspecting person who is exposed to a tuberculosis individual. The dog could very easily carry the tubercle baccillus in nostrils, hair, or on paws. By coming in contact with an unsuspecting infant or a child from the neighborhood the dog can easily infect such child and infection in a child may ultimately mean active tuberculosis and possible death.

To prevent the dog from becoming a source of danger in carrying tuberculosis, we must see to it that dogs should never be allowed to remain in a household where we find patients with active tuberculosis. This perhaps is the only means of preventing transmission of tuberculosis through the dog because no matter how careful a person may be in isolating a dog in a tuberculosis home, isolation of a dog is a thing next to impossible. The dogs perhaps could be removed to another place until the patient with tuberculosis gets well. Under such conditions the dog should be given a skin disinfection and should be kept out in the open at least twenty-four hours. The ideal method of rendering such a dog harmless would be to take the animal to the nearest veterinarian who would give him proper care and treatment.

How to Prevent the Spreading of Disease by the Dog

The dog is the best companion in a household where there are no children. No one will deny this fact. A dog can stay in a household for many years and if only a few simple rules regarding prevention of disease would be followed the animal would never be a menace to the community. It is only because of ignorance and carelessness of the master that the dog becomes a carrier of disease and therefore a nuisance. Just as the careless human being will go down the street and cough into people's faces and thus spread disease, so will the dog carry disease if not properly educated. The master has a duty to perform in limiting the dog's privileges and educating the animal to be more careful.

In the presence of infectious diseases such as scarlet fever, diphtheria, measles, chicken pox, etc., we ordinarily quarantine the child and his relatives but we pay very little attention to the domestic pets, particularly the dog. Such diseases are primarily spread from one individual to another in the playground where two or more children will play and come in very close contact with each other. The dogs are usually very willing playmates of children in the neighborhood. In the presence, therefore, of diseases that are transmissible, we must quarantine not only the family but also the dog.

Some dogs which are brought over from other lands may carry certain diseases that are common in the regions from which they come. This is particularly true of echinococcus disease which is common in Australia and Brazil. The same thing is also true of certain flukes that are common in Japan and China and can be easily transmitted from one end of the world to another through the dog. Such dogs coming from other lands, therefore, should be quarantined for a certain

period of time and be watched for the presence of various communicable diseases that are common in the lands from which they come.

Rabies or hydrophobia is practically always transmitted from one individual to another through the dog. In cases of hydrophobia the dogs should always be kept in the house and never be allowed to roam around without being muzzled. If any dogs develop any symptoms that would suggest the presence of hydrophobia it is necessary to always isolate such a dog and watch it over a period of time. If it would be necessary to kill such an animal we must always without fail notify the local health authorities so that they would make a proper examination of the brain and the spinal chord for any evidences of rabies. It is a fact that in countries in which there are strict muzzling regulations the disease is entirely under control. In the United States there are no such regulations in force. For this reason our mortality rates from rabies are unusually high. It is evident that in order to prevent rabies we must follow the example of Germany and enforce the muzzling law literally and thus lower our death rate. It certainly does not do any harm to the dog to keep him muzzled when the animal is out on the street.

There are many stray dogs in our communities. These dogs eat out of ash cans and sleep in alleys and back yards that are full of filth and disease. The family dog, in answer to the call of the blood, may run with such a stray dog, become infected, and carry an infection into his master's home. We must dispose of all stray dogs by either giving them over to educational institutions for use in the experimental laboratories or else to the local anti-vivisection society who will either find a new home for the animal or perhaps dispose of the animal by suffocating it with illuminating gas. Just which is the best method of disposing of such stray dogs depends primarily upon the element that makes up a particular community. If the community is made up of men and women who are broad minded enough to see no malice in the use of the dog for experimental purposes, such dogs will promptly be transferred to the local educational institution to be used for experimental purposes. If on the other hand the community is made up of old fogies who must be anti-something in order to be happy, the dogs of that community that have no homes will be taken over to the pound and killed by some means or other without performing any useful act for humanity.

In the home the dog should be trained so that he does not become a nuisance. At best being only a lower animal and not having the necessary mental qualifications that a man has in order to be of the same standard, the dog should be treated as an inferior but not un-

kindly. There is absolutely no excuse for anyone to allow the dog to lie in his bed. We spend a large portion of our lives in bed and I am sure we do not want to spend this part of our lives in between filthy and germ-filled sheets.

At the table the dog should under no circumstances be allowed to eat from the same plate as the master. In the first place it is disgusting and in the second place it is dangerous. In a series of 500 consecutive examinations of intestines of dogs for parasites we found that more than 95 per cent of the dogs contained intestinal parasites. The eggs of these parasites are commonly found in the mouth of the dog. What could be easier than to spread disease by this means? In order that we are certain that the dog is free from parasites, we must have a veterinarian administer vermifuges to the dog at certain periods and thus dispose from time to time of the worms present in the intestine of the dog.

The veterinarian is the man who is best qualified to treat the dog's skin and prevent the presence of mange, two types of which have been proved to be transmissible to man. The skin of the dog should be kept clean and free from fleas that usually carry the embryo of a tapeworm which is very common in the dogs.

We dispose of our excretions in sewers and use medication to render them harmless. In spite of our efforts in the disposal of our own sewage we pay no attention to the excreta of the dog and a mere wiping of the floor or the carpet is sufficient with the dog owner. The dog's excreta are just as dangerous as our own, and care should be taken to render these sterile and harmless. There is a long list of convenient antiseptics that can be used for this purpose.

The dog is the easiest animal to train to do tricks. He is very obedient and very persistent. The dog will try repeatedly until he learns to perform what he is expected to do. Such being the case, it should be a very easy task to train the dog to defecate in the yard at a certain specially appointed place for this purpose. The dog should be trained not to sleep in the bed or under the bed. One is just as bad as the other. Moreover, the dog should be trained not to lick the hands or face of an infant. It is a very discouraging sight, indeed to see a father or a mother kiss their own child in the mouth. More so if they allow their child to be poisoned by the licking of the innocent and unsophisticated dog.

The dog likes to skip out of the house and run around the neighborhood for new experiences. There are certain periods during the year when the dog wants to run out of the house more so than ordinarily. A castration frequently will keep the dog in his place when all the other means fail.

The most important consideration is that of treating the dog as a dog and not as a human being. The dog has rightfully earned for himself many privileges in the home. In most homes, however, the dog has been allowed more privileges than some of the human members of the household. It is in these homes that the dog is an innocent menace by virtue of these extended privileges. Be kind to the dog, play with the dog, keep company with the dog, hunt with the dog, but don't allow the dog to lick the baby's face, or eat from your plate, or sleep on, or under your bed. Regard the dog as a dog and not as a human and the dog will be a better and more useful friend.

How then are we to approach this problem? We cannot do it through regulations because no one will heed them. We have an excellent example of this in the 18th amendment. We can get results, however, if we make an effort to educate the general public to the dangers of indiscriminate contact with dogs. Such quotations as the following must be popularized so that even children may be able to repeat them.

1. Don't kiss a dog.
2. Dogs should not eat at the table.
3. Dogs should not sleep in your bed.
4. Everyday is a bath day for me and my dog.
5. Both you and your dog must see your doctors regularly.
6. Muzzle your dog and protect your neighbors.
7. No dogs are allowed in a sick room.
8. If you like your dog keep him at home.

With posters having such quotations or similar ones the public may be educated to the dangers of disease transmitted by the dog. In closing let us emphasize the fact that a dog should be treated as a dog and not as a human being.

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CLINICAL OBSERVATIONS ON THE PORTAL SYSTEM IN LARGE CONSUMERS OF SUGARS

BY

N. C. IKNAYAN, M. D.

Charleston, Illinois

According to U. S. Department of Agriculture statistics, sugar consumed in United States was 7 pounds per capita in 1821. In 1925 it reached 121 pounds per capita. The consumption of so much sugar is a radical departure from dietetic habits of the past. Has human economy accommodated itself to the new form of carbohydrates?

During the latter part of the 19th century, sugar had come to form a considerable part of American dietary, dietetic observers then advised against its use in hepatic cirrhosis and allied diseases. As per capita consumption of sugar grew apace, evidences of its toxicity multiplied. The portal system consists of veins draining the gastro intestinal canal, spleen, gall bladder, and pancreas, and of accessory portal veins. All the component veins unite to form the portal trunk which divides into two branches, one entering the right and the other the left lobe of the liver. As they course through the substance of the liver they break up into smaller vessels and capillaries forming interlobular and intralobular veins. At this stage branches of the hepatic artery, which have been associated with intrahepatic ramifications of the portal vein, become confluent with them forming sublobular veins and these in turn combine to form hepatic veins which enter vena cava inferior just below the diaphragm.

Portal circulation in its course toward the liver is not a closed system. There are several outlets connecting it with the caval system. Under normal conditions, very little, if any portal blood enters either vena cava or any of its tributaries, but when lumen of the portal vessels are narrowed from any cause, blood seeks an outlet through one or all three main collateral vessels, with the usual result that they become enlarged to accommodate the additional influx. Varices of esophagial and diaphragmatic veins may then form at and above the cardia and often give rise to sudden and fatal hemorrhages. Large varicosities in hemorrhoidal plexus giving rise to severe hemorrhoids, may be due to the same cause, or collateral circulation may develop through para-

umbilical into superficial abdominal, epigastric and thoracoepigastric veins distending them and converting them at times into varices. In the case of portal cirrhosis, this is the most desirable consummation.

In some cases of portal cirrhosis and in other cases where diagnosis of cirrhosis could not be made with certainty, venules are found in the thoracoabdominal region, with some regularity as to position, arrangement, and form. They usually appear at the fifth interspace or below, rarely they may be found as high as the fourth interspace. In a general way they parallel and overlie insertion of diaphragm in anterior thorax and extend as far as the axillary lines. Their distribution at times is symmetrical, suggesting an arch formed of filigree work of delicate rose color, fine stroke and outline. In well marked cases the arch may become a circle, commencing at the fifth or sixth interspace at the sternal line on both sides of the chest, paralleling and including costal insertion of diaphragm as far as mid axillary line and thence curving forward and downward, reaching within 2 centimeters of the umbilicus on both sides. I have observed two such cases out of more than 75. Usually the number, extent, and arrangement of venules are influenced by the size and degree of involvement of the liver. These venules may be less marked on one side than the other, or may be entirely absent on one side. It is possible to estimate the size and degree of involvement of the left and right lobes of the liver from the number and size of venules present on the respective sides of the thorax. They are present more often and are better marked on the left side than on the right, which conforms with the clinical findings that the left lobe of the liver is more often involved and farther advanced in sclerotic processes than the right lobe.

What is the significance of the venules? In some well marked cases of cirrhosis they are absent, in others, equally well marked, they are present. They are also present in cases where portal cirrhosis could not be diagnosed.

I paid careful attention to patients with venules, and soon had a theory. Almost all cases having well marked venules gave a history of consumption of large amounts of sugar over a long period. They were sugar addicts. Under a diet restricted only in matter of sugars, syrups, molasses, etc., almost without exception their subjective symptoms improved and venules became less marked and in some cases completely disappeared. Depletion by salines and fasting for a few days had similar effects. In a few advanced cases of cirrhosis they were uninfluenced, although the patients' subjective symptoms were relieved and improvement in general condition was the rule. A few illustrative cases follow.

L. H., 1926. Since the time he was able to climb chairs and reach the sugar bowl on the dining table, he has consumed sugar by teaspoonsfull at every chance he had. At 5 he had well formed symmetrically placed venules on his lower anterior chest. He was suffering from symptoms of hepatic insufficiency, had visible veins on the abdomen, and an enlarged liver (four inches). Sugar was prohibited but no other restrictions were made. He returned for examination two years later. Venules had disappeared, liver was one inch smaller, superficial abdominal veins were still large. This child has cirrhosis but progress is evidently checked. He had gained four pounds during last eleven months, liver was reduced one-half inch and he is in better health.

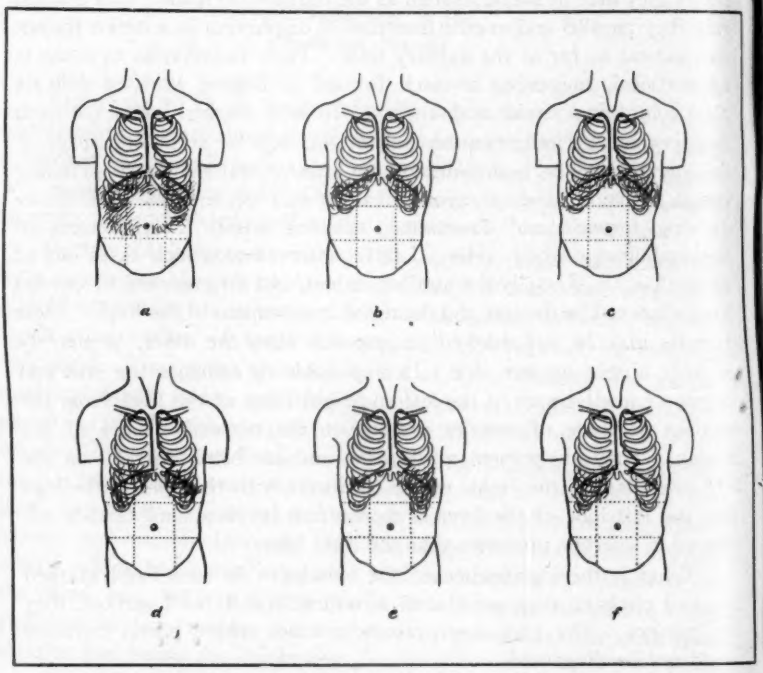

FIG. 1. *(a)* **E. A. as he appeared October 16, 1929; sugar was omitted from his diet.** *(b)* **E. A. as he appeared May 13, 1930.** *(c)* **An ordinary case of venules.** *(d)* **A shrub or dwarf tree type of venules.** *(e)* **Left-sided venules.** *(f)* **Right-sided venules.**

E. A., 50, a farmer, consulted me on October 16, 1929. He had been in poor health for many years, had lost 45 pounds in weight in the last few years. He was pale, coughing and expectorating pro-

fusely and looked spent. Examination of lungs revealed tuberculous fibrosis of both apices, the Von Pirquet test was positive; one sputum examination, negative for tuberculosis; low tension pulse, heart lacked tone. Lower margin of right lobe of liver reached the level of the umbilicus and that of left was slightly higher. Inspection revealed the most marked case of venules I had ever observed; they formed a complete circle, broken only at the umbilicus. A drawn circle would have bisected each venule at about a right angle. Superficial abdominal veins were all dilated, indicating that the portal system was seeking relief, and obtaining it by diverting part of its contents into the caval system, through para-umbilical and superficial abdominal veins. The patient was a sugar addict of the most aggravated type—he ate syrups and molasses, vast amounts of them, every day. Sugars, syrups, and other sweets were prohibited but there were no other dietetic restrictions. Carlsbad salts and iron were prescribed. Change for the better was surprising. He gained seven pounds in thirteen days, and visibly improved in appearance and spirits. In seven weeks the venules had grown faint and the liver was slightly reduced in size. Cough and expectoration were much diminished. He spent the following winter in Arizona, returned May 13, 1930, when examination revealed that the liver was much reduced in size and the lower half of the circle of venules had vanished. Superficial abdominal veins had become less prominent. He had increased 20 pounds more in weight. There were no evidences of clinical tuberculosis in this case.

I. J. M., 70, came under my care August 15, 1930, because of an acute gastro-intestinal upset. Venules were well marked—almost forming a semicircle; superficial abdominal veins, specially thoraco-epigastric veins, were much dilated. He was a chronic sugar addict. Depletion by catharsis and a brief period of abstinence from food reduced the size of veins and venules.

W. D., a retired locomotive engineer 63 years old, consulted me on April 12, 1930. He was a chronic diabetic having a well marked fibrosis in the left pulmonary apex. A sugar addict, he used three teaspoons full of sugar to each cup of coffee and four teaspoons full to each dish of cereal; blood sugar, 310 milligrams per cent. He had well marked venules on both sides and superficial abdominal veins were much enlarged. Liver, three inches palpable and hard, a diabetic cirrhosis. Sugar was ordered dropped from his diet, and the amounts of bread, potatoes, rice and milk were restricted. Six months later he returned, he had gained six pounds, looked well, was able to do several hours of work every day, his veins and venules were unchanged, his liver was hard, palpable and of same size as before.

Areas in which these venules are found are drained by perforating branches of the mammary, thoraco-epigastric, superior and inferior epigastric, abdominal cutaneous and para-umbilical veins. They neither individually nor collectively account for the venules which are enlarged capillaries that have developed in response to the reflected irritative or pathological influences emanating from the liver and overflowing from spinal roots, relayed over intercostal nerves to the area approximately overlying the organ where the irritative influences originated.

Among inveterate candy and fountain drink consumers, a gorge is not uncommonly followed by acute pain in the hepatic region. A girl of seven was subject to acute pain in the hepatic region. It was severe enough to keep her awake at night. She was an inordinate sugar eater. Recovery followed abstention from sugar.

J. B. S., 12 years old (April 9, 1931), has one bilious attack every month. He has a good appetite and is fond of sweets, eats in abundance; he soon becomes weak, nauseated, has sharp pains in the hepatic region, he vomits, has headaches, starves, there is mild acidosis with a large trace of indican and urobilin and a small trace of sugar in the urine. He gradually recovers, appetite returns, all discomforts from the hepatic region disappear to return again with the usual group of symptoms at the regular time. Removal of sugar from his diet caused a marked improvement and the next expected attack did not materialize. Medication consisted of calomel, bismuth, sodium succinate, and bile salts.

W. C., 17 (September 16, 1930), was greatly addicted to fountain drinks and at home was overly fond of sweets. He suffered from a feeling of fullness and discomfort in the hepatic region; soon the liver was tender and enlarged and acute distress supervened. For about one year he had dizzy and blind attacks of about one minute's duration simulating petit-mal, at times he came close to falling. The attacks usually came after meals and sometimes as often as twice a day. All these symptoms cleared soon after sugars were restricted.

In chronic cases the usual course is gradual decline accompanied by a feeling of tenderness on percussion, lack of endurance and ambition, distress and constant fullness in abdomen, unrelated to the time and kind of meals. These symptoms are usually due to hepatic insufficiency and the liver is atrophic in the majority of cases.

Sugars, syrups, molasses, and other sweets were toxic to them in the amounts they consumed. Besides they crowded important articles out of their diet and created a desire for stimulating foods and consequently their diet became deficient in some important factors.

These cases were treated by restriction or prohibition of sugars and in some balancing of the diets. Outside of salines and bile salts the treatment has been symptomatic. All those who remained under observation and treatment were greatly improved.

Venules are observed on the chest at various levels above diaphragmatic insertion. They approximately overlie sclerotic areas in the lungs. They differ in size, number, location, and arrangement from venules over the hepatic area.

In some cases of emphysema venules may be seen along the insertion of diaphragm. Cases of emphysema are rare in the author's practice who has never seen one with venules.

Chronic cholecystitis may at times be confused with hepatic insufficiency. The latter is of very common occurrence whereas the former is comparatively rare. Chronic cholecystitis with its vague digestive disorders, belching, sour eructations, sensation of weight and fullness in the upper abdomen, at times severe pains, chilliness, slight rise of temperature and local circumscribed tenderness should not be difficult to differentiate from hepatic incompetency. Hepatic incompetency may co-exist with cholecystitis and modify the symptoms.

Are the signs and symptoms described in this paper due to ingestion of excessive amounts of carbohydrates or due to irritative qualities of certain forms of carbohydrates, namely sugars? In a few cases I have seen venules with no history of sugar addiction and they confessed to the consumption of large amounts of potatoes, bread, and gravy. They were not well marked cases.

I feel justified in stating that in many cases venules are signs pointing to portal embarrassments and irritations, and in others to actual portal cirrhosis in the various stages of development. Well marked cases have generally been co-existent with sclerotic changes in the liver and the patients have invariably given history of sugar addiction of long duration.

USES OF BACTERIOPHAGE IN STAPHYLOCOCCIC INFECTIONS

BY

A. A. JANSON

North Shore Clinical Laboratory, Evanston, Illinois

Bacteriology is, comparatively speaking, a new science. During the short course of its existence, however, it has yielded an abundance of useful information and is now one of the most important of the basic medical sciences. Through bacteriology, the specific factors in the etiology of many previously obscure conditions have been disclosed; effective therapy, active and prophylactic, has been made possible in many instances; prognosis has been made more intelligent and rational. Every branch of clinical medicine has been perceptibly and favorably affected by the knowledge supplied through the study of this new science.

Immunology, the study of ways and means of protecting the body against bacterial invasion, is undoubtedly one of the most important of the contributions of bacteriology to clinical medicine. Bacteriology has afforded the basis for theoretical conceptions and actual accomplishments in immunology which have resulted in the frequent concept of immunology as a special science although it is essentially a component of the broader sciences of bacteriology. The study of immunity has opened a field so vast that it offers practically unlimited opportunities for research into problems but little understood as yet.

It is the writer's purpose to discuss but one phase of immunology and to submit impressions and experiences in the making and use of bacteriophages.

It is of interest to note that certain immunologic principles were utilized by primitive peoples, thousands of years ago. Some are known to have treated the bites of poisonous snakes by the application of a paste containing the specific poison of the offending reptile. It is said to have been a common practice among ancient Chinese people to remove the crusts from smallpox lesions and to apply these crusts to the nasal mucous membranes of unaffected persons, thereby effecting immunization through a rudimentary method of innoculation. Other immunologic practices have been recorded, procedures which were effective although empiric. The step between ancient empiricism and

modern rationalism and specificity in immunologic methods was a long one. The dawn of modern immunology begins with the time of Louis Pasteur.

Pasteur it was who conceived the idea that invading bacteria might be led to bring about their own destruction. His early work was done with the anthrax bacillus which was at that time a menace to the French sheep breeders and a serious economic problem to the nation. Through experimentation and practical application, he demonstrated that anthrax could be eradicated by vaccination. Thus were the basic principles of immunology established. Metchnikoff, a countryman of Pasteur elaborated on Pasteur's work and gave it a broader significance. Under the microscope he observed that leukocytes possessed the property of destroying and absorbing debris and bacteria and he it was that applied to them the name "phagocytes" from the Greek term meaning "eating cells."

Scientific experimentation requires a certain understanding of the underlying factors or principles of the problems under investigation. Although Pasteur and his followers had unfolded the basic principles of immunity, it remained for the German scholar, Ehrlich, to evolve a workable and understandable theory of their mode of action. He projected his famous "side-chain theory" which, while it may have been incomplete or imperfect, was plausible and understandable and stimulated experimentation which has resulted in many invaluable contributions to the advancement of clinical medicine in general and bacteriology in particular. Without such a working-rule as the Ehrlich theory, many valuable discoveries (such as the Wassermann reaction, based on the principle of complement fixation) would probably not have been possible.

One year before the death of Ehrlich in 1916, Twort reported his remarkable discovery, known as "Twort's Phenomenon." This was that bacterial cultures contain ultramicroscopic particles, developed by the organisms in the culture, which are capable of destroying the bacterial growth. Two years later, in 1917, the French scientist d'Herelle corroborated Twort's findings and, by improving upon his procedures, succeeded in elaborating a practically available substance which was capable of counteracting the activity of the bacteria in the culture from which it was isolated. These particles were regarded as ultramicroscopic bacteria by d'Herelle and he called his preparation a "bacteriophage"—something which eats or destroys bacteria.

Since d'Herelle made his first report on bacteriophage in 1917, more than two thousand papers have been published on the subject. Notable among these contributions is the extensive work of Besredka

whose procedures varied somewhat from those of d'Herelle. Besredka used old cultures to obtain the substance which he termed "antivirus" but d'Herelle and his followers used very young, actively growing bacteria. Arnold, Bordet, and others, with whom we are inclined to agree, believed that the ultramicroscopic substance known as bacteriophage or antivirus is not a living substance but a ferment. Other valuable reports are those of Rice, Larkum, and Bozy.

Early investigators in bacteriology observed certain cultural irregularities in bacterial growth and noted that these irregularities were especially evident with bacteria from the intestinal tract. With the development of knowledge concerning bacteriophages, it was found possible in many cases, to isolate a phage from the feces of patients convalescing from infection, and also from sewage. This probably explains these cultural irregularities. Arnold, of the Illinois Public Health Department, has isolated a phage from Chicago River. Such discoveries are of clinical importance and open wide fields for the future of bacteriophage research.

When the use of a bacteriophage is contemplated in the treatment of an infection, it is of the utmost importance to first ascertain whether or not the available phage is active against the specific infecting bacteria. By obtaining a culture from the infected area, the efficacy of the phage may be tested in vitro before being used in vivo. The following method, a simple and feasible one, is used:

Make two cultures, one in 50 cc. of broth and one on plain agar. Incubate the agar culture for 12 to 18 hours.

Incubate the broth culture for 4 hours, then divide it among a number of sterile tubes, depending on how many tubes are to be tested.

Label one of these tubes "Control" and add nothing to it.

To each of the other tubes, add one-tenth volume of the phage to be tested. Label them properly for identification.

Incubate all the tubes for 12 to 18 hours or longer.

If any of the phages used are effective against the organism being tested, the cultures to which these tubes have been added will be clear. The control tube should be cloudy, indicating unimpeded growth.

Varying degrees of clearness may be observed in the different tubes. In such a case, the phage which has produced the clearest solution should be chosen for clinical use.

If none of the phages used will clear up the culture, it is an indication that none of them could be expected to be clinically effective. An autogenous bacteriophage should then be prepared. This may be accomplished through the "stepping-up process" as follows:

Make two cultures, one in broth and one in an agar tube.

Incubate both for 18 hours.

Filter the broth culture through a Berkfeld filter.

Innoculate the surface of an agar plate with a loop of filtrate and a loop from the agar tube.

Incubate the agar plate for 18 to 24 hours.

Pick out the abnormal colonies, those with the 'chewed' edges, and transfer them to another broth culture.

Incubate the new broth culture for 4 to 6 hours.

Add one-tenth volume of the first filtrate to the broth.

Incubate again for 24 to 72 hours.

If the broth becomes clear, it contains a specific bacteriophage; if not, the process may be repeated until it becomes active.

Filter the clear broth through a Berkfeld filter.

The filtrate contains the bacteriophage in the form for clinical use.

While it is extremely desirable, as mentioned before, that the available phages be tested in vitro against a culture of the specific offending organism before being applied clinically, it is not always possible or practicable to do so. Many conditions may make the delay inadvisable. A polyvalent bacteriophage may then be tried. The use of such preparations will not be uniformly successful, but they can do no harm and will succeed in many cases, provided the diagnosis of the type of organism is correct and the polyvalent phage contains the antagonistic substance for the particular strain. We now have a polyvalent bacteriophage which is effective against more than thirty strains of staphylococci and which has proved effectual in a number of cases where cultures of the infection organisms were not available.

Clinical Application

Most of our experience with the use of bacteriophages has been limited to its application locally at the site of infection and principally in the presence of staphylococcic infections. In some cases it has also been intramuscularly injected for a systemic effect. Local physicians have used our stock preparation and autogenous phages in the treatment of such varied conditions as infections in the external auditory canal and the nose, simple furuncles, multiple and persistent furunculosis, carbuncles on the neck and buttocks, secondary abscesses, etc. Their usual method of procedure is as follows:

About 1 cc. of the broth containing the phage is injected directly into the infected area.

A gauze or cotton dressing, saturated with the solution, is placed over the infected area, covered with oiled silk and held in position by a bandage or adhesive strips.

The dressing is kept moist by periodically saturating it with more of the solution.

When the infection is in the ear canal or the nose, pledgets of cotton saturated with the solution are left in the cavities.

Intramuscular or intradermal injections of the solution may be used in addition to the local treatment when indicated.

Results

The results from this treatment have been uniformily satisfactory. No failure has been encountered where the phage has been properly selected by typing in vitro previous to clinical application. Pain is promptly relieved, usually within a few hours, and a marked improvement is usually seen within twenty-four hours. When the infection is not too far advanced, abscesses are frequently absorbed without drainage. If the infection is advancing, localization takes place rapidly, drainage is established and often completed within forty-eight hours.

Discussion

Bacteriophage is made up of ultramicroscopic bodies which, whether they be bacteria or enzymes, are capable of reproduction as demonstrated through their growth in a culture. They reproduce at the expense of the bacteria in the culture which are dissolved and destroyed. Microscopic examination of a culture which has been exposed to an active bacteriophage shows no tract of bacteria or cell debris.

Repeated freezing of a solution of bacteriophage does not destroy its activity but heating to a temperature above 75° Centigrade does. Injection of a bacteriophage into an animal stimulates the production of an antibody that neutralizes the lytic action of the phage. The fact that there is a large amount of protein material in the bouillon together with the by-products of metabolism of the young culture of bacteria may be of significance.

Case Records

Case 1. **Because of an unusual circumstance attending the successful management of this case a rather full report is warranted. The patient was a woman, 60 years of age, a diabetic who had for a long period shown a constant blood-sugar level of 200 to 250 milligrams, although glysosuria was absent. For four years she had suffered from furunculosis constantly, most of the lesions appearing about the face and neck. The causative organisms were found to be staphylococcus albus epidermitis. We had made two autogeneous vaccines which had been tried without giving any relief. Her physician then determined to try a bacteriophage. Our polyvalent phage failed to destroy the organisms obtained from the infected area, in vitro. We used it locally regardlessly but it failed also. An autogeneous bacteriophage was then prepared which, in spite of being repeatedly stepped up, failed to cause lysis of the infecting organisms in the test tube. Finally, on purely empiric grounds, we prepared another autogeneous bacteriophage, using 2 per cent dextrose broth in place of plain broth. This phage proved effective in vitro.**

At this time, the patient was under the care of a surgeon, in addition to her regular physician, because of a carbuncle on the cheek. Because of her diabetes, the surgeon hesitated to incise it. Hot boric compresses irritated her and her condition was becoming serious.

When the dextrose phage was completed, the physician injected it directly into the carbuncle and applied a dressing saturated with the solution. Within two hours, the pain had subsided and, within 24 hours, free drainage had been established without the aid of surgery. The infected area was kept constantly covered with a dressing saturated with the bacteriophage and daily intramuscular injections were given.

The carbuncle healed promptly, without leaving a scar, and she has been entirely free from similar infections since that time, a period of nine months.

Case 2. A woman, 43 years of age, came to her doctor after suffering for three weeks from a carbuncle in the gluteal region. During this time, it had opened spontaneously and drained and closed again several times.

A culture showed a strain of staphylococcus aureus which was lysed in the test tube by one of our stock bacteriophages of a similar strain. The abscess was infiltrated with 1 cc. of the phage and the dressings kept saturated with the phage all night. Within 12 hours, the pain was relieved and free drainage established. After 24 hours more, the abscess stopped draining and healed rapidly, granulating from the base outward.

Case 3. A man, aged 52, presented himself with a furuncle within the nose. A culture revealed the staphylococcus aureus which succumbed to our polyvalent bacteriophage in the test tube. The nostril was packed with cotton saturated with the bacteriophage. This was left in place over night. The abscess was promptly absorbed without draining and no further treatment was necessary.

Case 4. A man, 28 years of age, was referred for typing of infection. He had a traumatic abscess on his leg which was causing him great pain. The culture showed the causative organism to be the staphylococcus albus epidermidis and the broth culture cleared after incubation with our phage No. 7 made from a similar strain.

The infection was spreading at this time. One cc. of the phage was injected into the infected area and the dressings were kept wet with the solution. Within 24 hours, the infection had localized but was still very painful. The area was re-injected with 1 cc. of the phage and the dressings continued as before. Drainage was established spontaneously and within 72 hours of the first injection, drainage was complete, pain was completely relieved and granulation was beginning.

Case 5. A woman, aged 55, had had a series of styes over a period of several months. The same condition had occurred periodically for the past several years. When seen by us, she had a row of draining styes which were causing great discomfort.

The culture showed the staphylococcus albus epidermidis as the offending organism and it responded, in vitro, to our polyvalent bacteriophage. Local applications of this phage for 24 hours caused complete disappearance of the styes and there has been no recurrence in the past two months.

Case 6. This case illustrates the necessity of using a specific bacteriophage for a specific organism. A man, aged 70, had a carbuncle on his back. He also gave a history of having lung abscess four years previously. It was

impossible to obtain constant cultures. It was a polybacterial infection showing various types of cocci and bacilli at different times. Our polyvalent bacteriophage was tried without success.

Case 7. An exceedingly painful condition was seen in a woman, aged 32, whose external auditory canal was literally filled with small furuncles. The canal was closed so tightly that she could hear nothing in that ear. She had been using a commercial preparation of bacteriophage in a jelly form for two weeks without effect. There was no drainage at the time we saw her and no culture was obtained.

A pledget of cotton saturated with our polyvalent staphylococcus bacteriophage was applied over the external ear and kept moist. Within 24 hours, the pain was notably decreased and drainage established. A culture was then made which revealed a staphylococcus which was sensitive to the phage used. Within 72 hours, the pain was entirely gone, drainage had ceased and granulation had begun.

Case 8. A woman, aged 37, suffered from a traumatic infection in the distal phalanx of one of her index fingers. When first seen, it was a spreading cellulitis, without localization, and streaks of lymphagitis were seen running up the hand and well above the wrist. No culture was possible at the time so the area of greatest infection was injected with one-half cc. of polyvalent bacteriophage and constant wet dressings, saturated with the phage, were begun. In 12 hours, the infection had localized and the lymphangitis had disappeared. Healing did not take place at once because considerable sloughing eventually took place but no more difficulty was encountered as far as the infection was concerned.

A culture taken after drainage had been established showed the staphylococcus aureus which was susceptible, in the test tube, to our polyvalent bacteriophage.

Case 9. A boy, aged 4, had an abscess of the lower eyelid. It was not draining and no culture was obtained. Local application of the polyvalent phage caused such rapid disappearance of the lesion that it was impossible to have the child returned for a culture or further observation.

Case 10. A surgeon, past 70 years of age, had been taking a series of vaccine treatments for arthritis for the past year. At this time, every injection was followed by an abscess and when seen by us he had about five abscesses on each arm. They were large and contained great quantities of pus although they did not cause much pain. Repeated cultures were obtained from a number of different abscesses but none of them showed any growth. The abscesses were sterile.

In spite of this each abscess was injected with 1 cc. of our polyvalent bacteriophage and dressings saturated with the phage were applied. The same procedure was repeated the following day. In two days all the abscesses had disappeared and there have been no recurrences, although the vaccine injections have not been discontinued.

Observations

Organisms with like cultural characteristics do not necessarily respond to the same bacteriophage. A culture of staphylococcus aureus may not be lysed by a phage prepared from another culture of staphylo-

coccus aureus. The same is true of staphylococcus albus. There are, apparently, numerous strains of similar organisms with similar cultural characteristics and the phage must be specific in order to be active. On the other hand, a staphylococcus aureus bacteriophage will, at times, destroy the staphylococcus albus and the reverse is also true.

This observation emphasized the fallacy of relying too greatly on stock preparations. Unless such phages are prepared from a large number of strains of the specific organism, failure will be frequent. It also substantiates our contention that, whenever possible, cultures of the infection organism should be obtained and tested, in vitro, for its reaction to a number of specific bacteriaphages or a polyvalent one. When a culture cannot be obtained, a polyvalent preparation should be used. The greater the number of strains represented in such a preparation, the greater will be the probabilities for success. When the available phages fail to destroy the culture in the test tube, an autogenous one should be prepared. Our own experience indicates that where a phage is inactive under laboratory tests, failure will attend its clinical use; and that in nearly every case where activity has been demonstrated in the laboratory, its clinical use will be attended by success.

Surface infections, especially in the region of the face, are usually caused by the staphylococcus albus whereas deeper infections such as furuncles and carbuncles, are usually caused by the staphylococcus aureus.

The local application of bacteriophage is now also being accomplished through the application of a salve or jelly with the phage incorporated into it. Our experience with this method is as yet too limited to discuss but, theoretically, it should have some advantages. Intramuscular and intradermal administration is also being largely used in the treatment of chronic infections, especially of the streptococcic types, with considerable success. Many cases of chronic arthritis, where the streptococcus is recovered from the nose, throat, rectum, or feces, have been successfully treated in this way.

Conclusion

Bacteriophage therapy offers a simple and unusually effective method of combatting many types of bacterial infection and opens a vast field for research. Its present accomplishments are limited but real; its future possibilities are unlimited and can only be conjectured.

X-RAY OBSERVATIONS ON STERILITY AFTER LIPIODOL INJECTIONS

BY

A. M. SWANSON, M. S., M. D., and T. ARTHUR JOHNSON, M. D., F. A. C. S.

Johnson Clinic, Rockford, Illinois

INTRODUCTION

The use of iodized oil in recent years in gynecological conditions has brought to light many new conditions that heretofore had to go unrecognized, except by subjecting the patient to a surgical operation.

By means of injection of the iodized oil, many pathological conditions are clearly demonstrated. The use of the oil, being antiseptic in character, is also thought to have some beneficial therapeutic action in certain types of inflammation of the genital tract, and again, the oil, being injected under a moderate amount of pressure, aids in dilating a narrow tubal lumen, and overcoming a moderate amount of contraction and spasticity.

The substance used in our investigations, was a 40 per cent iodine preparation, firmly bound in poppyseed oil. The preparation is marketed as "Lipiodol." Iodopin, used by some investigators, is darker in color, and is iodized, sesame oil. The lipidol is yellowish, transparent in color, and has the appearance of olive oil. It is a definite chemical compound, not merely a solution of iodine in oil. As a result, it is non-toxic and non-caustic. The ordinary tests have failed to reveal the presence of iodine in the urine following the injections. It is very impervious to Roentgen rays.

In order to render the cavity of the uterus and Fallopian tubes opaque to the Roentgen rays, various substances were used. Cary [1] used a solution of Collargol as the opaque medium for this purpose. Kennedy [2] employed a 10 per cent solution of sodium bromide, and Mocguot [3] used a suspension of bismuth as a means of demonstrating the shape of the uterine cavity. (None of these solutions produced a clear deep shadow.)

The use of iodized oil, however, dates back only to 1922, when Forrestier [4] reported the use of a 40 per cent combination of iodine with poppyseed oil.

Accurate knowledge of the condition of the Fallopian tubes is necessary for the complete examination of every sterile woman, as by far the most common cause of sterility in women is found to be in the Fallopian tubes. It is estimated by many gynecologists to account for as high as 45 per cent of the cases.

Technic

The patients and instruments are prepared as for operation. The cervix of uterus is caught with a tenaculum forceps, after insertion of a bivalve speculum. The canal is thoroughly cleansed with mercurochrome, and the mucous in the cervical canal previously removed with hydrogen peroxide.

A 10 cubic centimeter Luer syringe is used. The Ultzman-Keyes nozzle, consisting of a long canula, with rubber diaphragm about three centimeters from tip, fits close to cervix, and prevents the escape of lipiodol into vagina.

Gentle pressure is made, until the patient complains of slight uterine colic. The pressure is then released for a moment, and reapplied until the same reaction occurs. An X-ray picture is then taken, which is repeated in five minutes, and at times, a third picture taken, preceded by a hypodermic of atropine, if necessary, to overcome a possible spasticity. An interval of five minutes is allowed between each Roentgenogram, to give time for overcoming this possible spasticity.

Uses of Lipiodol in the Diagnosis of Sterility

According to Heuser [5], lipiodol has been used as a means of making an early diagnosis of pregnancy, which is often hard to determine when only a period or two have been missed.

Heuser's method consists of diagnosing pregnancy by means of intra-uterine injection of lipiodol, subsequent Roentgenization depending on the fact that when the gravid condition exists the uterus is already occupied and cannot be filled by the oil; whereas, when the uterus is empty, the oil permeates the entire cavity. According to this investigator, the injection of the oil does not terminate the pregnancy.

By means of the injection of the oil, and the subsequent Roentgen ray study, it is possible to outline the contour and patency of the lumen of the Fallopian tubes, and thus diagnose the location of the obstruction in cases of sterility due to this cause.

Cases of ovarian cyst have been reported by Stein and Arens [6], in which, after the injection of the iodized oil, the Roentgenogram

clearly showed the silhouette of the ovarian growth, in the shadow of the fundus.

Injection of lipiodol is of great benefit in determining the solution of the problem, when the patient says "I have had a pelvic operation, but I do not know what for, nor what was removed." She returns to find out whether she can become pregnant.

The injection of iodized oil, and subsequent Roentgenography, helps to determine the presence of submucous tumors of uterus, as demonstrated in one of our cases.

The presence of malpositions of uterus, as anterior displacement and deviation to either side, is clearly brought out by a study of Roentgenogram, after lipiodol injection into the uterine cavity.

Patients with leucorrhea have noticed an improvement of this condition following iodized oil injections, this factor being due, possibly, to the antiseptic action of the oil.

Our series, consisting of thirty cases, has been in line with the experience of other investigations, that injection of the oil is a harmless procedure, and when carefully performed, always results in some beneficial action.

The escape of the oil into the peritoneal cavity through the tubes, as indicated by the Roentgenogram examination, is proof of the patency of the tubes. This is called the "spill."

The exact mode in which the iodized oil is absorbed, and its ultimate fate in the body, has not been determined, although it is apparent that the absorption is probably by way of the lymph stream.

Case 1. C. B., aged 30. Married 5 years. Complained of primary sterility; normal menstrual history. Lipiodol injection performed, and condition found as in figure 1. Normal appearing uterus, Fallopian tubes, and ampullae. There is a normal amount of "spill", or evidence of some of the iodized oil having entered the pelvic cavity. This patient shortly after became pregnant, indicating that the injection of the iodized oil was a determining factor.

Case 2. E. C., aged 40. Married 10 years. Complained of primary sterility. No history of pelvic infection obtained from patient, after repeated consultations. On physical examination, the uterus appeared to be smaller than normal, the adnexia not showing any evidence of gross palpable pathology. On operation, all the pelvic organs were found firmly matted down with dense adhesions, which extended upwards, involving the small intestines. The proximal portion of tube was separated from adhesions, and severed, so as to leave it open for possible entrance of ovum. On account of the extensive mass of adhesions, a complete plastic operation was not deemed advisable. A later consultation with the mother of the patient, brought out the information that at the age of 14 the patient had been confined to bed for two weeks with a pelvic disturbance, which no doubt accounted for the pathology present.

Case 3. U. B., aged 30. Married 5 years. Complained of sterility. Patient had an ectopic pregnancy on right side three years ago, at which time the right tube was removed, and since, she has been unable to become pregnant. This explains the absence of the Fallopian tube on the right side. The deviation of the uterus to that side is evidently brought about by adhesions at site of old pathological condition, and subsequent operation.

Case 4. O. L., aged 33. Married 4 years. Complained of primary sterility. X-ray findings indicated a non-patent right tube, and a normal left adnexia. The uterus deviated to right, associated with a partial blockage of right tubes, suggesting old adhesions pulling the uterus to the right. This patient subsequently became pregnant, and gave birth to a normal baby with normal labor.

Case 5. S. J., aged 40. Married 10 years. Complained of menorrhagia and sterility. The X-ray determination in this case was repeated, on account of the absence of the presence of the oil in the uterine cavity, but the same result was obtained. On operation, the uterine cavity was found completely occluded by a sessile submucous fibroid.

Case 6. P. L., aged 34. Married 6 years. Complained of primary sterility. The patient received an injection of lipiodol, and was subjected to a Roentgenological examination. The findings are shown in figure 6.

Case 7. E. F., aged 22. Married 3 years. Complained of dysmenorrhea and sterility. The patient was given an injection of iodized oil, and a pelvic Roentgenogram was made, as shown in figure 7.

Case 8. D. R., aged 35. Married 7 years. Complained of primary sterility. The patient received an injuction of lipiodol on two occasions, with the same results as shown in figure 8. Patient was advised to submit to an operation for resection or dilatation of portion of Fallopian tube, but to date has not had the operation performed.

RESULTS

In our series, we had three cases, who had been married for periods ranging from three to five years, and were unable to become pregnant. All of them become pregnant a short time after the lipiodol injections. This, we believe, has some direct bearing, as a result of the test, possibly by the antiseptic properties of the oil, or the dilatation of the tubes.

In one case, we were able to diagnose the presence of an intra-uterine tumor, which caused a menorrhagia. This condition was confirmed by operation with removal of the tumor.

Other cases that had lipiodol injections and Roentgenography showed obstruction at various points along the course of the tube and malposition of the uterus.

CONCLUSIONS

1. Roentgenological visualization of the uterus and Fallopian tubes, after the intra-uterine injection of iodized oil, furnishes a valuable means of exact gynecological diagnosis.

2. In case of sterility, the procedure gives us information as to whether the tubes are patent or not, and also localizes the site of occlusion.

3. The technic is simple, but strict aseptic precautions must be taken.

4. Properly performed, the test outlines the uterus and the narrow portions of the Fallopian tubes with great distinctness.

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EXPLANATION OF FIGURES

Fig. 1. X-ray appearance in normal subject, after injection of lipiodol. U—triangular area shows cavity of a normal uterus; T—normal narrow canal of isthmus of tube; A—tortuous and somewhat distended ampullae of tubes; S—"spill" representing lipiodol that has escaped into pelvic cavity; K—Shadow of the Ultzman-Keyes nozzle of speculum in vagina. This uterosalpingogram was obtained by injection of 6 cc. of iodized oil.

Fig. 2. X-ray appearances after injection of iodized oil. No evidence of any lipiodol having entered either Fallopian tube, indicating complete obstruction of both tubes. This pathological condition was confirmed at operation, which showed both tubes to be completely matted down in pelvis by adhesions.

Fig. 3. X-ray appearances in Case 3, after injection of iodized oil. The body of the uterus is well visualized by the oil. The uterus is markedly enlarged, and tilted to right. The adnexia on left side are unusually distinct. The Fallopian tube is well marked out on the left side; ampullae is markedly dilated; there is no evidence of any tube on right side.

Fig. 4. X-ray appearances in Case 4, after injection of lipiodol. The right Fallopian tube, half the length of the one on the left, which terminates in the ampullae, is somewhat tortuous; some of the lipiodol escaped through the ampullae into the pelvic cavity.

Fig. 5. X-ray appearances in Case 5, after injection of lipiodol. The region of uterus is indicated by a few small linear lines; there is no evidence of any of the iodized oil having entered the tubes or peritoneal cavity.

Fig. 6. X-ray appearances in Case 6, after injection of lipiodol. T—isthmus of Fallopian tubes; A—distended tortuous ampullae, indicative of hydrosalpinx of Fallopian tubes. Some of the oil ecsaped into the peritoneal cavity.

FIG. 7. X-ray appearances in Case 7, after injection of iodized oil. On the right, the oil has reached the ampullary portion of the tube; on the left, the tube is of smaller size, and ends in a dilated ampullae beneath the uterus.

FIG. 8. X-ray examination in Case 8, after injection of iodized oil. The tube on the left is about 2 centimeters long, ending blindly; on the right, a trifle longer, but showing a very small ampullae, and no evidence of a "spill."

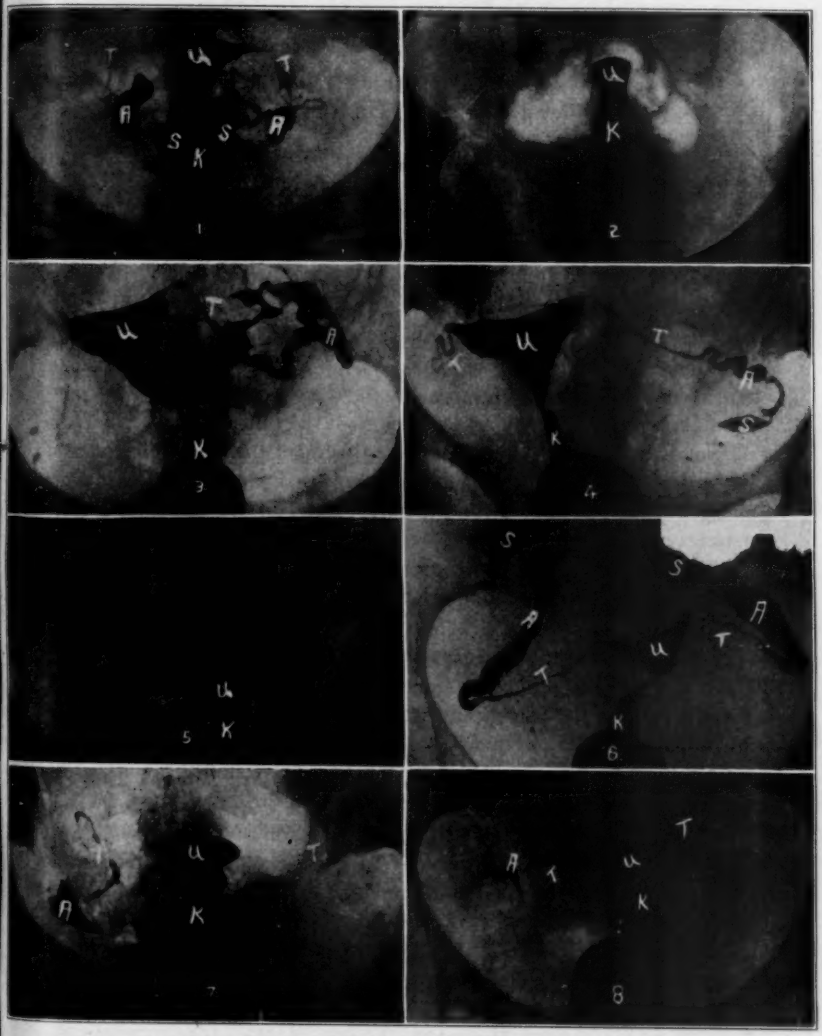

PLATE I.

SKIN DISEASES AMONG STUDENTS

BY

RUTH HERRICK, M. D.

University Clinics, University of Chicago

I. DRY AND OILY SKINS

Oddly enough, students, like the rest of the world, have skins that lead to some type of discomfort. Those with excessively dry skins are predisposed to itching in winter, or whenever the air is warm and dry. Such skins also chap easily in windy or cold weather, and often sunburn in summer rather than tan.

The other extreme, however, is more common: skins with an excessive oil production. This results in enlarged pores, blackheads, and finally the pustules of acne.

Acne occurs by preference on the face, upper back, chest, and shoulders. It is particularly common during the "teens," when the oil glands take part in the metabolic adjustment that the entire glandular system is undergoing. Hence doctors used to say, "Leave it alone and grow out of it." But that is hardly good advice when the disease may leave disfiguring scars, as well as cause untold embarrassment to children in their most self conscious age. Acne *can* be helped, but it takes the full cooperation of both patient and doctor, for many months.

The first aim is to keep the patient from manipulating the spots. Have the doctor, remove all comedones and open the large pustules. Tell the patient that blackheads do not depend on the manner of washing the face, but result from oily secretions held by large pores, and are black on top from oxidation by the air. Have him throw away his wash cloth, and wash the face with clean fingers only.

Keep the carbohydrate content of the diet on a low level by entirely avoiding sweets and pastries. Allow the patient no white bread, and only small quantities of potatoes, but make up the needed bulk by other vegetables, fruit, milk, cream, meat, and eggs. Take care that he has good elimination. Keep the kidneys active and the bowels free.

Finally, and this is the factor usually neglected, rid the scalp of dandruff. For seborrohea is to the scalp what acne is to the face, and from the same cause. Have him shampoo twice weekly or oftener,

and rub a good alcoholic tonic vigorously into the scalp every night. This will stimulate circulation of both face and scalp.

But kindly remember that acne is not cured in a day, and yields only gradually to the best type of treatment.

II. Common Contagious Diseases Among Students

Scabies, or "the itch" is to be mentioned only in passing. It is a frequent invader of even our "nicest" families, because of the ease of transmission by contact or clothing. It is no disgrace to catch it, but quite the opposite to keep it! But a word of warning. Too much treatment makes the skin itch worse than the disease; so follow your doctor's orders, and stop treatment after a few days as he directs.

Ringworm of the feet is such a commonplace, nowdays, that every good gymnasium, locker room or shower has its contribution to offer. The symptoms of itching, maceration between the toes, and the formation of small blisters have been so well described by the advertising profession, that I will not dwell on them further.

Ringworm is in reality a fungus, preferring the deep skin layers to any other habitat. Moreover, certain people have a greater susceptibility than others, and pick it up on public beaches, where their companions never seem to acquire it. Treatment belongs to the dermatologist, but prevention of re-infection consists of wearing fiber sandals while in showers, lockers, and to the edge of the swimming pool. These slippers should be discarded frequently. Recently there has been advocated a footbath of sodium thio-sulphate, or hypo, before entering the gymnasium or shower.[1]

With nearly the same universality, we see students from grade school to postgraduate school, infected with palmar and plantar warts. Such a sudden occurrence among groups of people, points to an infectious etiology, although none has been deciphered as yet, but we are assured that they are probably caused by a filterable virus. Methods of treatment are entirely destructive, such as X-ray or the fulgurating spark.

More rarely, but occurring with unfailing regularity every year when the wrestling season starts, we have students come to us with "molluscum contagiosum," or warty, button-shaped elevations. This infection is harbored by the wrestling mats, and seems to be resistant to any type of sterilization to which the mats are subjected. Treatment consists in curretting out the individual lesions with a sharp metal spoon, and it takes a well trained wrestler to "take his medicine and like it."

[1] Gould, Wm. L., Jour. Amer. Med. Ass'n., Vol. 96, No. 16. April 18, 1931.

III. Sympathetic Instability Group

Our main contact with students, however, consists of a group coming largely from the graduate schools; or perhaps school teachers spending their summer "vacations" at the University. These people come to us in multitudes, complaining of a diversity of itching conditions, varying in location from the eyelids, nape of the neck, genitalia and anus, to fingers, ankles, and forearms. They are unanimous in one thing—the itching was there first, then scratching or rubbing brought on dry, well defined plaques or scattered papules of so called "dry eczema." These lesions are lichenified, scale covered, and frequently fissured. The condition is designated neurodermatitis.

Such people form an interesting personality study. They are high-strung, mentally alert, usually physically active individuals, never content with their attainments, but always striving for more knowledge or bigger and better positions. Some bite their finger-nails; all have nervous mannerisms. On questioning, we find that they have always been good students, usually leading their classes in grades, and sometimes in outside activities also. One or both parents has been of similar nature; often very exacting.

Others come to us complaining of severe attacks of urticaria. Hives in adults, in our experience, are not often instigated by a particular article of diet, but come only when the patient is fatigued, or "let down" after living on "nerve." This signifies a fatigued nervous system. One of our medical students has hives regularly during every examination, but for the rest of the quarter is quite free.

A third group come in with deep seated vesicles on the hands, and have excessively moist palms. The old diagnosis of "dysidrotic eczema" expresses the condition, but the personality of the patient expresses the reason.

These three groups depend upon an underlying vaso-sympathetic instability, in which the skin reaction is only a symptom of the fatigue or stress of the individual. Such people have usually been the rounds of many doctors, and have tried every salve and local application. But one thing they have never tried—that is *rest*. And that alone in many of them, effects a cure.

In obtaining a personal or family history from such patients, it is not unusual to have them mention asthma, hay-fever, hypertrophic rhinitis, migraine headaches, or colitis. Often this group of diseases will be scattered through a family, each person may have one or several manifestations. The patient attributes this to diet, or "acid in the blood," and the Allergists, who have studied these people in detail,

make many skin-tests, and tell the patient he is allergic or sensitized to certain internal or external factors. But the skin tests do not tell the whole story, and the resulting diet is usually inefficient for this type of patient; for it does not get at the cause. The relationship of these medical and dermatological conditions with the exhaustion background had not been clear until Stokes of Philadelphia, pointed toward such evident etiology as a common basis.

Our conclusion is that a complacent attitude in life, and a regular vacation each year, play a more important rôle in successful attainment than had ever been acknowledged.

PAPERS IN PSYCHOLOGY AND EDUCATION

EXTRACT FROM THE REPORT OF THE SECTION CHAIRMAN

The papers published herewith were presented at the meeting of the Psychology and Education Section. The following two papers on the program were read by title only:

"The Significance of Reading Ability at the College Level," by Herbert L. Klingbeil, Carthage College, Carthage.

"Tests of Athletic Ability," by Coleman R. Griffith, University of Illinois.

The average attendance at the meeting was about twenty-five, the maximum attendance about thirty.

M. M. Maynard, Monmouth College, Monmouth, Illinois, was elected chairman for the 1932 meeting.

(Signed) EDWARD F. POTTHOFF, *Chairman.*

HEALTH SUBJECT MATTER IN THE NATURAL SCIENCES

BY

CLAUDE S. CHAPPELEAR

Illinois College, Jacksonville

INTRODUCTION

Teaching children the knowledge and skill necessary to maintain themselves in good physical health is generally accepted as one of the chief objectives of education. A complete program of health education as administered in public schools includes three types of activities:

1. Health Inspection.
2. Physical Education.
3. Health Instruction, either by special periods devoted to health instruction or by correlation with other subjects.

This study is limited to a consideration of the third phase of the program, health instruction, and is further limited to a study of the possibilities of health instruction through correlation with courses of four natural sciences, (1) general science, (2) biology, (3) chemistry, and (4) physics, of the secondary school level.

Anyone familiar with the present high school curricula realizes that the content of natural science courses has large areas of subject matter that definitely relate to health instruction. For example, we know that principles of sanitation are taught in general science and biology; that tests for detecting adulterations in food may be taught in chemistry, and that the anatomy of the eye is taught in connection with the study of the lens in physics. To repeat, the problem stated briefly is: (1) to determine quantitatively the percentage of health content in the subject matter of general science, biology, chemistry, and physics as taught in secondary schools, and (2) to determine the nature and scope of the health content in the above natural sciences.

Obviously, in order to determine how much health content is found in the natural sciences it is first necessary to determine upon the definition of health subject matter. Fortunately Dr. Ruth Strang,[1] in 1926, made a study of the health content of the subject matter in

[1] **Strang, Ruth, Subject Matter in Health Education, Bureau of Publications, Teachers' College, Columbia University, New York City, 1926.**

fourteen textbooks and eighteen courses of study for health instruction. She carefully analyzed the content of these textbooks and courses of study and distributed all subject matter under twenty-six headings. The contents of Strang's list, supplemented by material in three textbooks on health and hygiene, were accepted as guides in defining health subject-matter.

The next step of the study was to determine the best measures of what is actually taught in the natural science classes. For reasons sufficiently obvious to need no discussion in a paper of this length, textbooks, courses of study, and final or college entrance examinations were accepted as the best objective measures of what is taught in high school courses of natural science.

Methods Used in the Study

The first analysis in this investigation was of the contents of twenty textbooks on natural science, five each for general science, biology, chemistry, and physics. These textbooks were those most frequently mentioned by prominent high school teachers and college instructors who were asked to name the five leading textbooks in their fields of specialization. In each of these textbooks a record was made of the number of printed lines devoted to subject matter that was also covered in the content of regular health courses.

The total number of lines of health subject matter in each textbook was divided by the lines per page to figure the total number of pages of health subject matter. Special adaptions were made for cuts, tables, and diagrams; for pages whose lines were not uniform; for blank or partly blank pages; and for questions, summaries, or exercises. Hence, the pages of health subject matter for each textbook reported were complete full pages.

The number of page equivalents devoted to health subject-matter subtracted from the total number of pages of instructional matter leaves the number of pages of non-health subject matter. The percentage of health content is computed upon the basis of the total number of pages of instructional matter rather than upon the number of pages of the complete textbook.

The second analysis was of forty recent and representative courses of study, five state and five city courses each for general science, biology, chemistry, and physics. All topics in the natural science courses of study that were likewise found in courses of study for classes in regular health courses were accepted as health subject matter.

The third analysis was of the thirteen sets of College Entrance Examination Board questions and the twenty sets of New York State

Regents' Examination questions on biology, chemistry, and physics for the years 1916-1926. A record was made of all questions or portions of questions that could be answered with a knowledge of health subject matter. Since each question and portion of question in these examinations was given an arbitrary value in points, to be awarded for the correct response, it was possible to secure a definite ratio between health subject matter and the total subject matter. In borderline cases where the subject matter necessary for the correct response applied equally to health and non-health subjects, one-half of the credits allowed for the correct response was assigned to the health count.

In carrying out the fourth part of this study, a checking list containing the two hundred seventy-six statements which Strang[2] had found to occur five or more times in her investigation was submitted to two hundred teachers, fifty each of general science, biology, chemistry, and physics. These teachers checked those statements which they presented to the class in the subject matter of the natural science which they taught, and indicated roughly the amount of class time given to each statement.

Findings

Table I displays the results of five different analyses of the subject matter taught in biology. In each analysis the percentage of subject matter of biology that is also offered in courses for health instruction is given. Thirty-seven per cent of the subject matter of five biology textbooks was definitely about health. Forty-three per cent of the subject matter outlined in five state courses of study and 32 per cent of the subject matter of five city courses of study was likewise about health. The information required to correctly answer thirteen college entrance examinations in biology is 33 per cent health subject matter and to answer twenty New York State Regents' examinations is 32 per cent health subject matter.

When the five above measures were averaged it was found that 36 per cent of the subject matter of biology is also included in the courses for health instruction. Similar studies were made for general science, chemistry, and physics with the exception that examination questions were not available for general science. It appears that the College Entrance and New York Regents' Board did not feel that general science was sufficiently well organized to receive credit for admission to college, hence, no examinations were given in this subject.

[2] *Op. cit.*

TABLE I

HEALTH CONTENT IN HIGH SCHOOL BIOLOGY

Amount and Extent of Biological Subject Matter Devoted to Health Content, as determined in Five Biology Textbooks.

SECTION 1—TEXTBOOKS

Percentages and Pages of Health Content in Five Biology Textbooks.

Textbook and Author	Pages for all subject matter	Pages for health subject matter	Per cent of pages for health
Biology and Human Life (Benjamin Gruenberg)	480.45	201.83	42.01
New Essentials of Biology (George W. Hunter)	412.05	139.23	33.79
Biology for Beginners (Truman J. Moon)	516.05	180.59	34.99
Biology and Human Welfare (Peabody and Hunt)	477.11	201.65	42.23
New Biology (Smallwood, Reveley and Bailey)	603.71	197.54	32.72
Total for five textbooks	2,489.37	920.87	36.99

SECTION 2—STATE COURSES OF STUDY

Percentages and Topics of Health Content in Five State Courses of Study for Biology.

State Issuing Course	Topics for all subject matter	Topics for health subject matter	Per cent of topics for health
Minnesota	635	302	47.56
New York	801	318	39.70
Vermont	162	60	37.04
Virginia	248	74	29.84
Wyoming	1,051	486	46.24
Total for five State courses	2,897	1,240	42.80

SECTION 3—CITY COURSES OF STUDY

Percentages and Topics of Health Content in Five City Courses of Study for Biology.

City Issuing Course	Topics for all subject matter	Topics for health subject matter	Per cent of topics for health
Austin, Texas	362	93	25.69
Bayonne, N. J.	174	94	54.02
Denver, Colo.	716	167	23.32
Muncie, Ind.	363	180	46.83
St. Louis, Mo.	178	44	24.72
Total for five city courses	1,793	578	32.23

SECTIONS 4 AND 5—EXAMINATION QUESTIONS

Percentages and questions upon health content in thirteen college entrance and twenty New York State Regents Examinations in Biology.

Examinations	Questions upon all subject matter	Questions upon health subject matter	Per cent of questions upon health
College Entrance	195	64.8	33.23
New York State Regents	300	95.8	31.93

A summary of the results of the analysis of the subject matter in general science, chemistry, and physics appears in Table II. It was found that the percentage of subject matter offered in these courses that was also taught in health courses was for general science 33 per cent, chemistry 11 per cent, and physics 3 per cent.

Stated in terms of school weeks this means that a student taking a thirty-six weeks' course in high school science receives the equivalent of thirteen weeks instruction in health subject matter if he takes biology; eleven weeks if he takes general science, three weeks if he takes chemistry; and one week if he takes physics.

TABLE II

SUMMARY OF ALL ANALYSES OF THE HEALTH CONTENT IN THE SUBJECT MATTER OF NATURAL SCIENCES

Showing the percentage of total subject matter devoted to health content in each analysis for each natural science.

	Percentage of Total Subject Matter Devoted to Health in Each Science			
	General Science	Biology	Chemistry	Physics
Page analysis of five popular textbooks	30.78	36.99	9.16	3.05
Topical analysis of five state courses of study	34.49	42.80	16.65	2.76
Topical analysis of five city courses of study	34.91	32.23	14.45	6.13
Credit point analysis of 13 college entrance examinations	.....	33.23	5.79	2.82
Credit point analysis of 20 New York State Regents' examinations	.....	31.93	7.77	1.03
Average	33.36	35.44	10.76	3.16

THE HEALTH SUBJECT MATTER THAT SCIENCE TEACHERS UTILIZE

The number of health statements checked upon the check list of two hundred seventy health topics submitted to teachers indicated that science teachers fully utilize the health content of the subject matter of the natural science courses. Many teachers offer additional health content which does not appear in the text books or courses of study.

Twenty per cent of the health statements are checked by three-fourths of the general science teachers. Fifty-five per cent of the statements are checked by more than one-half of the teachers. Statements concerning *disease* were most often checked, indicating that general science teachers hold this phase of health instruction to be of predominating importance.

Forty-seven per cent of the health statements are checked by three-fourths of the biology teachers. Eighty-two per cent of the biology teachers check three-fourths of the statements. There is a tendency

for biology teachers to supplement the textbooks in developing *structure and care of the teeth* and *elimination of body waste.*

Chemistry teachers show little agreement upon the health subject matter taught in chemistry. Statements concerning foods, however, were most frequently checked.

Physics teachers check few health statements, but there is a tendency to agree upon the statements that concern *eyes—structure and care, and air—ventilation and breathing. Structure and care of the ear,* practically ignored by physics textbooks, is taught from supplementary sources by a large number of physics teachers.

General Science

The type of health subject matter most fully treated in general science is: *foods—nutrition and digestion; disease—cause and prevention; cleanliness—personal and general; air—ventilation and breathing;* and *eyes—structure and defects.*

Sleep, rest and fatigue, and elimination of body waste, which are treated but slightly in general science, deserve more complete consideration.

Exercise and posture are not treated as fully in general science as in the pure health courses. This is no doubt desirable because exercise and posture are essentially matters of habits and skills which can be more adequately developed in the classes of physical training than in science courses.

Health education is commonly offered as one of the principal objectives of general science. This study shows that the health objective is well supported by the subject matter content of the general science curriculum.

General science occurs first in the sequential order of the natural science courses of high school level and therefore reaches many students who withdraw from school before they take other science courses. With respect to numbers of students enrolled, general science is by far the most important science course. For these reasons general science should be given the preference of the health subject matter to be offered, and subsequent science courses should then be adjusted to prevent unnecessary and uninteresting overlapping.

Biology

The type of health instruction receiving greatest emphasis in biology is: *foods—digestion and nutrition; disease—cause and prevention; heart and circulatory system; mental hygiene and psychology; posture, exercise; care of teeth;* and *air—breathing and ventilation.*

The chief criticism of the health content of biology is the nature of its overlapping with the health content of general science. Figures are not available to show the number of students who take both general science and biology but the number is undoubtedly large. Overlapping that presents previously studied facts with different and new emphasis is consistent with good teaching practice. Overlapping that is a mere repetition of subject matter without a change of emphasis is, however, very likely to prove uninteresting and tiresome. Numerous examples of the latter type of overlapping between biology and general science were found, most particularly in the subject matter upon *food* and *disease*.

In the most desirable overlapping observed, general science in the ninth year emphasized the nature of the subject matter, showing the relationship of the subject matter to the individual and to the environment; the course in biology, following in the tenth year, presents essentially the same subject matter, but is continually given new relationships by the emphasis upon the actual functioning of the human body.

Chemistry

The type of health subject matter most fully presented in chemistry is: *foods—nutrition and digestion* (which was consistently more than 50 per cent of the health content of chemistry), *cleanliness—personal and general, safety—personal and property,* and *clothing—hygiene and care.*

The variation in the amount of health subject matter in chemistry was largely due to the extent of treatment of a few special health classifications (particularly those named above) rather than to the inclusion of a wider range of subject matter by the courses devoting greater percentages to health content.

There appears to be a tendency on the part of those chemistry courses devoting liberal content to *foods* to repeat subject matter that has been well presented to students who have taken either general science or biology. It would seem that the subject matter in chemistry upon *foods* should not be a mere review of the elementary principles of a balanced diet or the preservation and care of foods in the home, which are treated in some detail in both general science and biology. Chemistry can make a unique contribution to the study of *foods* by taking advantage of the student's previous training and directly proceeding to teach the chemical composition of foods, the chemical changes involved in digestion, and the industrial chemistry concerned

in food production. Writers of chemistry courses can study with profit the content upon foods in courses of instruction that usually precede chemistry.

Physics

The health content of physics was very largely confined to the following types of subject matter: *air—breathing and ventilation; eyes—structure, defects and care;* and *food—nutrition and digestion.*

It is the opinion of the writer that the possibilities of teaching health in physics are not fully realized in present high school instruction. For example, while the physiology of the eye is reviewed to good advantage in connection with the physics teaching of the lens and light, the physiology of the ear is scarcely mentioned in physics subject matter as it might well be in connection with the study of sound.

In some physics textbooks, thirty to forty pages are devoted to the subject of sound. The origin of and the medium for transferring sound are studied in detail, the course of the vibrations is considered up to the human end-organs, but there is no word regarding the manner in which the sensation of sound is perceived by the human brain.

The writer observed the instruction of one physics class where the teacher introduced interesting supplementary work in connection with sound. Starting with the lungs and vocal cords, showing how human sounds are produced, and following the sound through the physical medium to the organs of the ear that receive the sound waves, she ended with a study of the nerves that carry the sensation of sound to the brain. The human organs involved in this cycle of producing and receiving sounds were studied and discussed. No doubt there are many other physics teachers who thus supplement the available physics subject matter with applications to health.

Application of the Findings

1. The findings of this study should direct the attention of natural science teachers to the health subject matter that is incumbent upon them to teach, because of the nature of the health content of the natural sciences.

2. The natural science teachers are herewith presented data revealing the nature and scope of the health content of the natural sciences from which they may evaluate their teaching, and perhaps readjust points of emphasis.

3. Accurate knowledge of the health content of each of the natural sciences should prevent deadening and wasteful overlapping. Undesirable overlapping between general science and biology, especially in the subject matter concerning *foods* and *disease* exists to a considerable degree. In many instances, the subject matter in chemistry of *foods* is a mere repetition of the treatment in general science and biology, and is no doubt unnecessary and uninteresting to students who have studied either.

4. When overlapping occurs between general science and subsequent natural sciences, general science should be given preference of health subject matter and other courses adjusted to prevent unnecessary overlapping.

5. The findings of this study direct the health teachers' attention to the contributions to health education that can reasonably be expected from natural science courses. Such knowledge can enable the teachers to take advantage of correlating them with their own instruction rather than merely repeating health subject matter previously taught in natural sciences.

6. The interrelations of the health instructor and science instruction are so intricate that teacher training institutions might with profit require students preparing to become natural science teachers to take some courses in health education. Such a procedure would enable the future natural science teachers to make more profitable health adaptation and interpretation from the science subject matter they will teach. On the other hand, college courses in natural science for future health teachers would enable them to appreciate better the scientific basis of the health subject matter they will teach.

7. From the findings of this study, the curriculum builders can better recognize the possibilites of health instruction in the formation of courses of study for natural science. In the making of health courses of study, recognition can be given to the health subject matter of the natural sciences.

8. The high school administration can learn from this study the health instruction that should be yielded from the natural science courses of the curriculum, and hold science teachers responsible for the health subject matter of each course.

9. The high school administration can profit to advantage in using the findings of this study in working out the health instruction received by individual students. Dr. Thomas Wood in a lecture before one of his health classes at Teachers College, Columbia University, made the following statement:

"It is incumbent upon the administrative officer responsible for the educational outcomes of the curriculum to bring together the contributions that all subjects may make to the important objective of health education. Any subject that, taught effectively, can contribute to health education should be recognized as a part of the health program, and its relationship and integration in the unified and rational program definitely provided for."

10. In conclusion, the writer is convinced that the problem of health education is sufficiently great to challenge the best efforts of every contributing department. It is not a question of the natural sciences taking over the sole responsibility of teaching health. It is the problem of the natural science department to make the most of the potential applications to health that lie in the inherent nature of the subject matter of its courses. Health education is only consummated with the changes of behavior of the individual. With the science department assisting in providing a basis for intelligent healthful living, through scientific facts that aid in interpreting proper health principles, it is paving the way for health and physical habits and ideals of living without which all factual knowledge of health is futile.

TESTS OF ATHLETIC ABILITY

BY

COLEMAN R. GRIFFITH

University of Illinois, Urbana

If it were possible to make a description of a football player just as we find him in the midst of a game, we should end our study, no doubt, with a large and complex list of traits and skills. We would find that our football player has a certain amount of skill in running, jumping, dodging, pivoting, straight-arming, throwing, tackling, blocking, catching a ball, outguessing his opponent, keeping himself cool-headed, controlling his emotions, motivating his conduct, and the like.

This is but a suggestion of the number of items that might be listed; but our main concern is not to make a list of the whole bundle of skills and traits which any man may be at any moment. On the contrary, there are certain questions about these traits that we should like to ask. We might, for example, ask about the origin and the course of development through which each skill or trait has passed. This question would introduce us to all those problems known as the problems of learning. No man is born with any of the abilities we have named and it follows, therefore, that the games he has played, the practice periods he has used, and the experiences through which he has lived have made him what he is at the moment we find him.

In the second place, instead of asking about origins and processes of development, we might ask about the way in which a man differs in each of these various skills from the other men with or against whom he is playing. That is, some men are slower or faster, stronger or weaker, more or less alert, more or less quick, than their fellows. This would introduce us to that part of psychology known as the study of individual differences[1]. In the next place, we might ask whether all of the skills we could name were being used at their highest level. That is, we might ask whether, on this particular day and at this particular moment, our man was just as good as he had trained himself to be. These questions would introduce us to all of the problems that hover around the words "efficiency" or "condition."[2] Finally, we might ask whether it would have been possible on some previous occasion, say

[1] Ellis, R. S., The Psychology of Individual Differences, 1929.
[2] Poffenberger, A. T., Applied Psychology, 1928.

two or three years before, to predict how expert a football player a man was going to be. That is, in advance of training or in advance of the actual acquisition of a high degree of skill, is it possible to tell what the potential power of a man is?

This last question, and most of the others as well, depend upon the further question as to whether it is possible to measure either the skills of a man or the resources which he may have for gaining a skill. Several answers have been given to this question. The first says that the rate at which a man learns any given skill or a whole group of skills is the best way of finding out something about the innate qualities of a man. In other words, it is assumed that there is a high correlation between learning, on the one hand, and intelligence, on the other. It is assumed also that there is a high correlation between learning and motor intelligence.

It must be clear that this method of testing athletic ability will work only providing a coach has enough time to make it work. It is the method which is actually used in industry and in education as well as in coaching. A man is put to work or a child is given a desk in a schoolroom and we proceed to find out how fast each can learn and how proficient each can become at the end of a week, a month, a year, or a decade. The chief objection to this method of studying either the potential power of a man or his actual skill lies in the fact that it consumes too much time. To use such a method would be like building a bridge out of whatever lay at hand and then studying the sustaining power of the bridge by waiting for increasing amounts of traffic to go over it.

It is just as natural for men to seek short cuts to knowledge as it has been for them to search out short cuts to wealth, and there are, therefore, other proposals for measuring the athletic talent of a man, just as there have been other proposals for measuring his intelligence. One such method proposes that a football game, for example, is made up of a series of fundamentals such as running, throwing, catching a ball, charging, blocking, punting, tackling, and the like. If we desired, therefore, to see how talented a man was, we might ask him to run 100 yards in his football togs, throw a football at a target, tackle a tackling dummy, kick a ball, dodge, pivot, change pace, straight-arm through and around a series of obstacles, and so on. In this way, it would be possible to measure the speed at which he can run, the accuracy with which he can throw, the distance which he can kick, and his relative quickness and coördination in doing some of the other tasks we have named. This method has recommended itself to coaches and to

students of athletic sports because it is fairly quick, because the measures can be made with a fair degree of accuracy, and because it seems to bear some relation to a man's ability to play a game[3].

In using this method of testing either attained or attainable skill, it is necessary to find those activities which are most prophetic. In basketball, for example, it is possible to measure the skill which a man has in shooting at the basket, record the time that it takes him to dribble the ball one hundred feet, measure his accuracy in a direct pass or a bounce pass, and so on. The argument behind measures of this kind is that each one of these feats is an activity essential to the playing of basketball and that it ought to be possible, therefore, to tell from them[4] something about the game-playing ability of a man.

This method of studying athletic talent can be made even more abstract by simplifying the movements to be made. It is clear, of course, that running in basketball has many elements in common with running in football. Likewise, throwing a basketball or baseball has some elements in common with throwing a football. The coördination used in shooting baskets, dribbling the length of the floor, or making a bounce pass to a team-mate has many elements in common with dodging, straight-arming, batting, and so on. Through this process, one may arrive at a group of words which seem to describe muscular ability as such. That is, they seem to describe muscular ability apart from the special uses to which this ability is to be put in the playing of any one of the games. The words at which we may arrive are agility, balance, muscular or bodily control, flexibility, strength, quickness, and the like[5]. Having reached this point, it now becomes possible to devise tests not for maintaining balance while being tackled or while doing a gymnastic stunt, but for sheer balance itself[6]. It becomes possible to devise a test of strength apart from the strength that it takes to play any one of the games[7]. We might, for example, ask a man to stand still with feet together and eyes closed and maintain this position for a given number of seconds without moving. We might ask him to hold his left foot in his right hand behind the right leg and hop around on one spot for as many times as we think will give a measure of his skill. We might ask him to jump into the air as high as he can or jump into the air and make a half or full turn in either direction[8]. In other words, we prepare a list of stunts which are exceedingly simple and

[3] The list of events named comes from the field test used in football at the University of Illinois.
[4] Brace, D. K., Testing Basketball Technique, Amer. Phys. Ed. Rev., 1924, 29, 159-165.
[5] Brace, D. K., Measuring Motor Ability, 1927.
[6] As for example, the Miles ataxiameter.
[7] Bovard, J. F., and Cozens, F. W., Tests and Measurements in Physical Education, 1930, Chap. IV.
[8] Brace, K. D., *op. cit.*

which we believe to be related in one way or another to such general terms as agility, sense of balance, flexibility, quickness, strength, and the like[9].

Tests of the two kinds just mentioned have come into increasing favor during recent years. In the first group of tests the aim, as we have seen, is to take such fundamentals of the game as seem essential to the game, standardize them so that times, distances, or degrees of accuracy can be measured and then find the relation between these results and the actual ability of a man to play the game from which the tests were derived. In the other case, the aim is to take such phases of skill that seem to cut across all games and measure these skills in the most formal and objective way possible[10].

There is still a third way to measure athletic skill, the way that takes the student of such matters into a laboratory rather than to the athletic field or to a gymnasium where stunts can be tried out and measured.

This third way may be illustrated by using the concept of quickness. One way to measure quickness would be to ask a man to run one hundred yards at his best speed. Another way would be to give him a stimulus, say a brief flash of light, and tell him to react to the light, just as quickly as he could by pressing a telegraph key. The light would have some resemblance to a pistol shot; but instead of running one hundred yards, the subject would move just a single finger. In the one case, the experimenter would have a measure of the rate of running and in the other a measure of what is called reaction time. It is obivious that the reaction time would be much simpler than rate of running, for running involves not only speed but a high degree of coördination in leg muscles as well. In a simple movement of the finger the amount of coördination is reduced almost to a minimum. We should have a test, then, for sheer quickness[11].

This third way of measuring athletic skill seems to run more deeply into the heart of the problem of motor intelligence than any of the other types of measurements. We may illustrate the situation by still another example. Throwing a basketball at a basket calls for what is called eye-hand or eye-limb coördination. The same thing would appear in throwing a forward pass, in batting, or in any other form of athletic skill where it is necessary to react to an object that is being seen. Obviously, it would be difficult to make an accurate study of any one of these skills if we were to remain on the athletic field. The

[9] See Bovard, J. F., and Cozens, F. W., *op. cit.*
[10] Bovard, J. F., and Cozens, F. W., *op. cit.*, Chap. VIII.
[11] Reaction time studies were among the first to make a science of psychology. See Griffith, C. R. Psychology and Coaching, 1928, Chap. XIII.

football passer very rarely throws his pass in the same way twice in succession in the actual playing of the game. On one occasion, he may be guarded more closely than on another. He may be more fatigued at one time than at another, and so on through all of the variable conditions that would appear on the field of play. Such a study of eye-hand coördination would be then not only a study of coördination itself but a study of coördination in relation to a vast array of uncontrollable and unpredictable events.

If we are to get at the heart of the problem of coördination, all of these variable factors must be eliminated and this means that eye-hand coördination must be taken into a laboratory where practically nothing is left for study save the simple movements involved in tapping the various areas on a rotating disc, keeping track of an irregularly moving object, and the like. The subject of the experiment can always be put into approximately the same frame of mind, the task to be done can be made so simple and automatic that all measures are measures of the same thing, and thus an approach made to the study of eye-hand coördination as such, apart from all reference to definite athletic skills.

It is upon this third type of measurement that the Laboratories for Research in Athletics at the University of Illinois have spent a great deal of time. Among the pieces of aparatus used in the laboratory is an outfit for measuring rate of reaction to light, sound, and pressure, a device for measuring eye-hand coördination, a device for measuring flexibility of coördination, a device for measuring the muscular sense, a device for measuring learning ability, a device for measuring the span of attention, and so on. In every case the apparatus aims at some fundamental aspect of motor intelligence.

The great question one faces in such studies of athletic talent is, of course, the question of the relationship between the measures themselves and the actual ability of a man to play a game. The ability to play any game rests, apparently, upon three sets of factors. Other things being equal, the man who has among other traits and skills the shortest reaction time, the best muscular coördination, the most useful power of attention, and the best memory ability, will make the best athlete. But before he becomes a good athlete two other factors must be considered. In football a man must have courage; but up to the present time no way has been found of measuring courage save by watching a player during a game in order to see how far he is willing to abandon himself in making a tackle, how much he flinches when tackled, how long he can endure pain and fatigue, and the like. The third factor which enters into the makeup of any athlete is his power to use his quickness, his flexibility, and his memories in an under-

standing way. That is, an athlete must have a motor as well as a mental level of intelligence.

We have, then, three sets of conditions. There are men who are fast, well coördinated, and the like. If they lack either courage or understanding, they will not make an athlete. If they have the first items conjoined with courage, they may make a much better record. A great athlete occurs only when understanding or intelligence is combined with courage and with the motor qualities measured in the tests.

THE PERIL OF EDUCATION THROUGH EXPERIENCE

BY

GEORGE A. BROWN

Bloomington, Illinois

INTRODUCTION

The title of my paper turns out to be entirely negative in its meaning for this ten minute discussion. In that time I cannot do justice to the perilous experience of expert knowledge. If you will note that the common root syllable *peri* in these words is derived from *peril*, you will see that the given title is tautological. I hope you will accept the following paper as at least something different from an education through experience[1].

My thesis is that the mental life of mankind is a capacity of nature to do the work required to test knowledge, to give skill to talent, and to secure intelligently directed social conduct. This means that civilization is to be studied as a phenomenon of the energy of nature working as common human nature to advance the fellowship of mankind, and that social fellowship, rather than economic needs, is the central control. Society, and not the individual, is the unit for the final outcome[2].

The four topics presented in this discussion are I—Method in Human Conduct; II—The Physical Basis of Mind; III—The Social Basis of Mind; and IV—Three Natural Steps in Education.

METHOD IN HUMAN CONDUCT

Method is the large question before both psychology and education. The central issue, stated with violent contrast is:

Shall we leap before we think? or
Shall we think before we leap?

[1] Logically, the peril of education through experience is the peril of limitation to immediate environmental opportunities and to ideas which depend upon the operation of habits.

How to study is a prime requisite of education, and this means how to integrate new ideas and experience with the total resources of life in a way to guide thought and talent and the insight of results towards true conduct.

[2] Mental life in this connection means a capacity to work for common understandings, appreciations, and plans, and to use nature's resources and man's social powers for a developing civilization.

Mankind acts both ways, or thinks he does, and the adage has been "Look before you leap." Hence my title. Evidently, in the early life of mankind, a new experience was considered as a leap in the dark. Must it always be so?

The empirical method, even as Dewey uses it, obtains knowledge only from experience. The contrasting method is the scientist's very fruitful objective method with its fundamental assumption that there is, not only an order of nature to be experienced but also that nature is an energy—a capacity to do work in a number of different ways which may be understood. For instance, there are nature's ways (1) in the gravity of mass; (2) in the chemism of atoms; (3) in the metabolism of organic cells; and (4) why not in the sociality of persons? The way nature works in each of these fields is determined when, in each case, present knowledge is so organized as to point the way to what may now be anticipated as hypothesis but needs to be discovered as true. The objective method gives the direction and anticipates that which is to be proved. It is possible to do this on the general hypothesis that nature is an energy. The tool used by science is the *crucial* experiment in which the various effects of the energy are so integrated as to establish the fact that nature works that way in that field of observable relations[8].

How shall we express the idea of the energy of nature as it acts directly within mankind? The evidence of such an energy is our progressive human civilization itself. This energy takes form in human thought, judgments, appreciations, and in social conduct. It cannot take true form in what Dr. Dewey calls "A false psychology of an isolated self."

The physical scientists have been puzzled to apply their concept of the energy of nature to human life. Thomas H. Huxley gave the name "artificial personality" to human energy acting to maintain civilization, although he recognized that "conventions of honor are stronger than law, or morals, or religion, and shame drives the weakest to suicide." From his statement, it would seem that restraint of antisocial actions is the *artificial* in personality only because this restraint is needed by the psychologically isolated person. If nature in mankind has no capacity to work for sociality, then individual man tends to revert to the untrained being who struggles only for animal existence. Science is obstructed by the negative assumption that a *natural* personality is not active in promoting social relations true to human

[8] The beginning of modern physical science may be credited to the work of Galilleo in his effort to define force in terms of mass and velocity. He established the use of the hypothesis and of the necessary crucial experiment.

welfare. Science cannot prove the negative. Why assert that civilization is less permanent than is organic life when men give their lives to maintain it?

Rightly defined, sociality would be a good name for the energy of nature as it works in all persons for the common good. Public opinion would then be considered as the *weight* of combined personal opinions due to the gravity of human energy acting throughout mankind. My point is that the *gravity of physical mass;* the *chemism of substances;* the *metabolism of organic life;* and the *sociality of human beings* are, each in its own way, *forms of action* for the energy of nature. Magic is not involved in the hypothesis of a natural energy at work within mankind in a way to produce the organizations of human society.

The fact that this energy works through the power of knowledge, the skill of talent, and the anticipation of good from directed conduct, and that it is difficult to express with the uniformity of a mathematical formula, does not leave us helpless to define it. Gravity varies directly as the mass and inversely as the square of the distance. The terms are quantity and distance.

If we say sociality, as an energy of nature, varies in its effects *directly* with the fullness of knowledge, perfection of skill, clearness of anticipation, and *inversely* with some power of the separation from the source of human energy by an isolated self, the terms are conditions and oppositions.

It is to such hypotheses that the objective method of science owes its unlimited fruitfulness[4].

The Physical Basis of Mind

What is the physical basis for such mental life? I can only offer the following quotations from C. Judson Herrick, the anatomical student of brain action. He says in his "Brains of Rats and Men" (page 350):

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[4] The hypothesis of a sociality gives to every unit of conscious *thought—talent—insight of ends* a dynamic capacity to do work. It makes each condition of consciousness a unit of mental experience and at least a reserve center of activity for a fellowship union in civilized human life. What has been called the stream of awareness provided by the senses is not the source of human consciousness, though it may be the cause of the reaction of biological instincts.

The mental action of human consciousness is made possible by a special brain equipment of freely-acting associative neurons making up most of its cortex tissue. With this equipment, mental experience acts as an orienting power of direction, and patterns are formed by the associative neurons which retain the relations of *elements in the experience* and finally make connections for the interaction of *thought—talent—insight* between minds through acquired common symbols. The union of effort to carry out anticipated activities is thus made effective.

This hypothesis must rest, therefore, upon the demonstration of an adequate physical basis of mind and upon a psychological basis for the realization of the results of this capacity of nature. Nature's way in human life is not that of determinism. The limitations on free action are due to as yet inadequate preparation and to the not too many possibilities for human life in this world.

"The human type of plasticity of behavior is the very antithesis of habit, it is a new vital mode."

Again, and concerning the great mass of associative neurons, each with its pattern and symbol holding web of thought material, he says: (page 320)

"The income of energy and material which has accumulated throughout the entire preceding course of life, in short, the totality of our experience, can be drawn upon and made immediately available on demand. It is the whole personality that reacts to meet every situation."

One more quotation is perhaps enough to indicate the equipment of man's physical brain for action with his fellows to advance civilization. He says:

"My judgment and my forecast of my own proposed action are determining factors in shaping a decision or 'making up my mind' to a choice just as truly as are my hereditary or established habits or my (physical) condition of hunger."

The greatly increased amount of cortex brain tissue in man is free to hold emergizing patterns and symbols needed in the conscious processes of mental action, and provides the physical needs for nature's way of working within mankind for progressive civilization.

The Social Basis of Mind

The implications for psychology and education may be called startling. The first principle to recognize is that nature's energy is available for *conscious* use only when we know her way and try to work in accord with that way. Psychology and education make a false start in assuming that bodily contacts with things awaken consciousness and that social action starts on the same plane as animal action. Nature puts the human infant under conditions that just reverse this order. The infant's mind awakens to direct consciousness of person with person acting together. Thought requires a background of energizing mental patterns as a basis for anticipated kinds of response. Thought is at first secured only through conscious interchange of fellowship mental activities.

To-day psychology needs to discover the facts in *human* intercourse. It is a mixed field of investigation. Some of these facts draw men's mind together and secure loyalty to *proved knowledge, support of skilled talent,* and *devotion to organized* and intelligently directed social effort to secure more comfortable conditions of living for all, and fuller realization of the capacities of each in good, true, and beautiful living itself. These are the facts of the gravity of what we have named sociality. Other facts indicate the obstructions to this work by an isolated self. It is necessary to overcome their interference with the advance of civilization.

This field of psychology will be closely related to education, particularly to adult education. No person can reach a maturity much in advance of the maturing civilization, and education is an ever continuing process.

Three Natural Steps in Education

(a) Human intercourse is also the source of educational training for children and youth. Training is needed to meet the needs of growing powers of the mind. Each young *brain* grows and the cortex tissues increase in capacity to gather mental energy. The neuronic patterns and symbols by which the material for thought and judgment and appreciation and anticipation of ends is secured, come from fruitful associations. The first need here is to discover the facts of educational experience. The situation is different from adult education. This is due to the teacher's relation to growing brains and to the *need to establish,* as the background for thought, *the pattern materials* and neuronic energy for mental action. The indications are that these background experiences come in good part from play activities properly directed to include, at the age of the children, the kind and the amount of symbols and patterns possible in the associative neurons at that age. Play experiences are necessary as they do not complete the actual nervous reactions to biological needs, but are retained in the cortical tissues as pattern material with energy for action when the mind itself acts. Up to what age the play attitude is helpful has yet to be determined.

(b) Nature's way in youthful minds is to anticipate a social relationship to be reached at maturity. To reach the anticipated place in society, the youth seeks training and knowledge as a necessary preparation. This is a definite student attitude but the school may enlarge the aims to include broader culture.

(c) For mature minds, active in the actual affairs of the community, there are indications that nature's way is the *anticipation of improved service to society* and of *enlarged opportunities* for individuals *through associative relations* and better organization in all activities.

Leadership is depended upon. That leader is helpful whose foresight is good. He leaps in the true direction of human progress when he anticipates nature's way of sociality and prepares the means for the next step.

USE OF THE PROBABILITY-TABLE IN ELIMINATING POOR STUDENTS FROM TEACHERS COLLEGES

BY

HELEN R. MESSENGER

Northern Illinois State Teachers College, DeKalb, Illinois

Teachers' colleges are badly in need of an easily understood and easily manipulated plan for eliminating poor students. Any device that will meet this need should be scientific, but as these colleges are in general without research departments, it should be simple and not time-consuming. This study has attempted to build up such a device.

The major problem of the study is: How can teachers' colleges eliminate unpromising students early in their freshman year so that the time of the students and faculty may be conserved for more profitable use?

As all authorities on the subject agree that a combination of measures is better for predictive purposes than a single measure, and, further, that mental test scores, high school averages, and pertinent subject-matter tests all correlate positively with college success, these measures were used in this study. Furthermore, as teachers' college and normal-school success shows a significant, positive relation to teaching success, these measures can be used for prognosis such as this study aims to develop.

For four years the Northern Illinois State Teachers College at De Kalb has been testing its entering freshmen with standardized tests. At no time has the number of students tested been less than 200. After some experimenting with other tests, the results of the following tests were selected for use in this study.

1. Otis Self-Administering Tests of Mental Ability—Higher Examination.
2. Mills Selective Test on Fundamentals of Arithmetic.
3. Cross English Test.
4. Haggerty Reading Examination—Sigma 3.
5. Pressey-Richards Test on Understanding of American History.

High school grades, of course, were also available for use. High school averages were obtained by averaging English, foreign language, science, and history grades. The five sets of scores from the tests and these high school averages made six entering measures.

Composite scores were made of these mental test scores, achievement test scores, and high school averages. This was done by dividing the raw scores of each of the six measures into deciles directly and then finding the average number of deciles for each person. With this set of measures and students' honor points, at the end of their first quarter in college, a probability-table was arranged. The combined table for 1927 and 1928, using each measure divided into ten parts, follows:

TABLE I

Probability Table, Showing Relationship Between Combined Six Entering Measures and Honor Points Received First Quarter in College. 1927 and 1928, 515 Cases.

Average Deciles, Six Entering Measures	Honor Point Deciles 1	2	3	4	5	6	7	8	9	10
10	..	..	..	..	3	7	9	18	12	51
9	..	..	..	6	2	16	20	14	21	21
8	..	4	4	0	13	11	14	13	24	17
7	4	12	6	15	14	9	15	14	6	5
6	7	16	8	10	16	10	9	16	6	2
5	13	14	6	9	11	10	13	8	14	2
4	15	9	7	10	17	15	6	12	9	..
3	16	19	10	9	13	13	7	3	8	2
2	16	9	28	20	9	9	7	2	..	..
1	29	17	31	21	2	..	..	..	..	..

Deciles, Honor Points

Deciles on 6 Measures	Honor Point Deciles
10=8.3—10	10=Above 8
9=7.5—8.2	9=8
8=6.8—7.4	8=7
7=6.1—6.7	7=6
6=5.3—6.	6=5
5=4.8—5.2	5=4
4=4.1—4.7	4=3
3=3.5—4.	3=2
2=2.5—3.4	2=1
1=1 —2.4	1=0 and Below

The table is interpreted as follows:

A student who stood in the highest decile (D_{10}) of his group in average deciles on the six entering measures has 51 chances in 100 of being also in the highest group (D_{10}) in number of honor points his first quarter in college; 12 chances in 100 of being in the second highest decile (D_9) of his group in honor points; 18 chances of being in the third highest decile (D_8) in honor points; 9 chances of being in the fourth highest (D_7); 7 of being in the fifth highest (D_6); and 3 of being in the sixth (D_5). He probably has no chance of falling below

D_5 in number of honor points at the end of his first quarter in college. Each row reads similarly. As D_5 in honor points indicates the minimum satisfactory amount of four honor points it represents the lower limit of satisfactory work in our college. Reading from the lowest row, 2 in 100 students made this satisfactory position (D_5) in honor points. The records for the students in the two lowest and the two highest deciles were followed through the second quarter. The entire group in the two lowest deciles in entering measures, made an average of 2.7 honor points for two quarters of college work. The group in the two highest deciles averaged 16 honor points for the same time.

It is clear that the two lower deciles in either case are not promising teachers' college material. If these students had been eliminated the first week of college, 36 students would have been dismissed the fall quarter of 1927 and 57 dismissed the fall quarter of 1928. Of the number, 93 for the two years, 13 according to the table could have made satisfactory records the first quarter in college. A detailed study of the record of these persons shows that of the 1927 group only two were given two-year diplomas and these two had a continuous struggle to keep their honor points up to the required standard. Of the 1928 group only two maintained a satisfactory average throughout the year and these two did not return to college for their second years' work. The history of this entire group in college throws suspicion upon the validity of the first term grades given them by instructors. On the whole the college would have been better off without these students. Some colleges will hesitate to eliminate so large a group. If the lowest decile only were eliminated only one student of the 48, considering the two years combined, would have had a chance of making a satisfactory college record. This student did not return the second year so was not given a two-year diploma. The case seems very clear: this college could eliminate all students making below 3⅓ as an average decile position on the proposed entering measures and do the teaching profession a service thereby. It is certain that students below a 2⅓ average decile position should be eliminated without hesitation.

A recommendation to similar institutions can be made from this experience. Gerberick, Kitson, and others have said that a probability-table could be built to forecast success in college. Their opinions were based upon general impressions, upon evident trends, or upon theory. This study has shown the working out of the theoretical speculation.

Any institution desiring an objective plan for eliminating unpromising students can follow the procedure outlined above and by a similar process build a probability-table for its own use based upon facts as they are found to exist. Faculties of teachers' colleges are aware of

the fact that they can make teachers who will succeed in the field, out of the average and higher groups among high school graduates. It is the lower group that is a source of anxiety to them. They will welcome an objective and simple plan for detecting the entering freshmen who have practically no chance of success in the teaching profession.

A SUMMARY OF EXPERIMENTAL INVESTIGATIONS IN ARITHMETIC

BY

MAX D. ENGELHART

Bureau of Educational Research

University of Illinois, Urbana.

The summary of investigations in arithmetic, of which this paper is an abstract,[1] is an attempt at synthesis of the findings of the experimental research relating to instructional methods in this subject, with recognition of their varying degrees of dependability. The criteria used in the evaluation of the experiments are as follows: (1) definition and restriction of the experimental factor; (2) control of pupil factors (equivalence of groups); (3) control of important non-experimental factors; (4) accuracy and validity of measures of differences in achievement; (5) justification of generalization. The extent to which the techniques used and the data collected in each of the experiments satisfied these criteria were taken as an indication of the dependability of the conclusions.

The summary is divided into the six major divisions as follows: (1) methods of learning and teaching the fundamentals; (2) methods of drill in the fundamentals; (3) methods of teaching verbal problems; (4) methods of providing diagnosis and remedial treatment; (5) methods of teaching the reading of arithmetic subject-matter; (6) methods of motivating learning activity in arithmetic. Space is too limited in the present paper to consider, in detail, the experimental research under each of these heads. The conclusions of the more interesting studies have been selected for presentation along with some general criticisms which may be made of the experimental research in this field.

Methods of learning and teaching the fundamentals. Buckingham has reported that it is more effective to teach pupils to add downward rather than in the upward direction. Recent research on transfer of training in arithmetic, notably that of Beito and Brueckner, appears to indicate that it is immaterial which direction is specified in teaching pupils to add. The conclusions of several investigations in the field of subtraction appear to favor the subtractive method of subtraction

[1] The summary is to be published as "A critical summary of research relating to the teaching of Arithmetic," Bull. 58, of the Bureau of Educational Research of the University of Illinois with Walter S. Monroe and Max D. Engelhart as joint authors.

rather than the additive method, and that the method of equal addition or carrying, in connection with the subtractive procedure, is more effective than decomposition or borrowing. None of the various methods of subtracting appear, however, to be significantly different in effectiveness. The conclusions of the experiments on methods of learning and teaching division, fractions, decimals, percentage, proportion, and denominate numbers are of so little dependability as to be unworthy of mention here.

Methods of drill in the fundamentals. Systematic drill in the fundamentals has been shown by several experiments to be highly effective. It has been shown to be more effective than incidental instruction such as occurs when the project method is used. The conclusions of G. M. Wilson indicate that a combination of systematic drill, and the less formal incidental instruction, is probably most effective as the incidental instruction contributes motivating influences while the systematic drill provides the distribution of practice essential if recognized objectives of arithmetic are to be attained.

Attention should be called in this connection to the significant contributions of research on the specificity of the calculation abilities, and on the relative difficulties of learning the different number combinations. These contributions have made possible the construction of drill materials shown experimentally to be more effective than those prepared informally by teachers. It seems reasonably true that drill materials which provide practice on the number combinations, proportionate to their difficulty, as revealed by the research just referred to, is more effective than drill material not prepared in this way. It also seems reasonably true, from the reported conclusions of a number of experiments, that drill materials should distribute practice over the number combinations, should provide practice on the higher decades in addition, and that it is relatively unessential to provide practice on number combinations in the reverse order. For example, if pupils are drilled on $6 + 3 = 9$ they will learn without other provision, according to Olander, that $3 + 6 = 9$. It is also reported that drill materials of a mixed nature are an effective means of securing maintenance of skill in the fundamentals.

Methods of teaching verbal problems. Monroe has concluded in a recent investigation that pupil responses to verbal problems are usually characterized by failure to employ critical reflective thinking. The findings of this, and other investigations, tend to show that pupils are most likely to make correct responses where problems are stated in familiar rather than unfamiliar terminology, when the problem statement is concrete rather than abstract or imaginative, and when irrele-

vant elements are not included. Systematic training in finding the data given in the problem, in deciding upon the calculations to be made, and in estimating the answer in round numbers are reported to be effective procedures for teachings pupils to solve verbal problems.

Methods of providing diagnosis and remedial treatment. Comprehensive and reasonably dependable experimental evidence supports the conclusion that diagnostic and remedial treatment is highly effective in the field of arithmetic. Conclusions have been reported which favor both individual diagnosis in which "first-hand observation is made of the actual work of the pupil" and diagnosis by means of diagnostic tests. Further research is needed before it may be concluded which method is relatively more effective. Expertly prepared drill material, providing practice for abilities diagnosed as weak, has been shown to be an effective means of providing remedial treatment.

Methods of teaching the reading of arithmetical subject matter. Reading ability has been shown to be an important factor in arithmetic achievement. The eye-movement studies of Buswell and John and of Terry should be referred to in this connection. While it appears certain that reading ability is an important factor in arithmetic achievement, further research is needed before a statement may be made with respect to the nature of its influence in the different situations represented by calculation examples and verbal problem statements of different types.

Dramatization and story-telling in connection with instruction in verbal problems; general training in reading, and the use of solution sheets containing information with respect to how problems should be read, and spaces for recording of data useful at different stages in the solution of the problem have been shown to be feasible means of teaching pupils to read verbal problems correctly. The research supporting this statement is very crude in nature. Further research must be conducted before dependable suggestions may be made with respect to the most effective methods of teaching pupils to read arithmetical subject matter.

Methods of motivating learning activity in arithmetic. Informing pupils of definite goals of achievement to be attained, and of their progress toward these goals, has been shown to be an effective means of stimulating learning activity in arithmetic. Competition, particularly individual rather than group competition, has been reported effective in securing intense effort in arithmetical learning activity. The use of this device appears justified in attempting to bring a class out of a slump in learning. Prolonged, or repeated, use is probably unjustified as the pupils are likely to acquire the attitude that victory in competi-

tion is the goal rather than the acquisition of arithmetical ability. Commendation and reproof have both been shown to be effective stimulants to learning activity. In arithmetic commendation appears to be more effective for most pupils. Reproof appears justified, however, where pupils are careless in the use of skills which they are known to have acquired. In closing, it should be stated that the most effective means of motivating learning activity in arithmetic is to request appropriate learning activity. Learning exercises should challenge the abilities of the pupils.

A general criticism of the experimental research on methods of teaching arithmetic. A critical examination of the experiments reported in this field indicates that few approach acceptability when measured by our criteria. In most cases, the experimental factors were complex in character and were not specified with precision. The more recent experiments seem satisfying with respect to equivalence of groups, but the large majority of the experiments may be criticized in this respect. Failure to control important non-experimental factors, particularly the zeal and skill of the teacher, is a criticism which applies to most of the experiments. Lack of validity is characteristic of many of the measurements made of achievement. Frequently, this lack of validity tends to make differences in achievement erroneously in favor of a given method. Finally, the characteristic use of small groups of pupils makes generalization in most instances unjustifiable. It may be concluded, therefore, that the findings of research in this field must be regarded as largely suggestive in nature, and much precise experimentation remains to be done before rules, principles, or laws respecting the teaching of arithmetic can be established.

A STATISTICAL SUMMARY OF RECENT EXPERIMENTAL STUDIES OF LEARNING AND MEMORY

BY

STEPHEN MAXWELL COREY

University of Nebraska, Lincoln, Nebraska

More than seven per cent of all the space in twenty-two psychological journals during the last six years has been devoted to experimental studies of learning and memory. The present report is an attempt to summarize certain trends of the experiments which have appeared in English during the years 1925 to 1930 inclusive.[1] Data are presented to bear on the following questions:

1. What journals have devoted relatively the greatest amount of space to experimental studies of learning and memory?
2. What has been the trend for the six year period with respect to the number of pages devoted to such studies?
3. What has been the size of the groups used in the learning and memory experiments?
4. What different kinds of subjects have been experimented upon?
5. What has been the age of the human subjects used?

It is evident that most of these questions can be most conveniently answered with tables. The figures given in the summaries are, in the main, reliable. No rigid set of criteria was established to determine whether certain studies were or were not concerned with learning or memory. The journals cited were examined and any reports of an experimental nature, regardless of their titles, that is, any in which factors were systematically varied in an attempt to determine their effect upon learning or memory, were included. The selection of materials was subjective, and some differences of opinion might exist as to whether all of the proper studies have been analyzed. One partic-

[1] The journals studied totaled 53,671 pages of psychological literature of which number 3,937 pages dealt with experimental studies of learning and memory. The following publications were examined: (1) American Journal of Psychology, (2) Archives of Psychology, (3) Australasian Journal of Philosophy and Psychology, (4) British Journal of Psychology, (5) British Psychological Monographs, (6) University of California Publications in Psychology, (7) Genetic Psychology Monographs, (8) University of Iowa Studies in Psychology, (9) Journal of Abnormal Psychology, (10) Psychological Clinic, (11) Journal of Comparative Psychology, (12) Journal of Applied Psychology, (13) Journal of Experimental Psychology, (14) Journal of General Psychology, (15) Journal of Educational Psychology, (16) Mind, (17) Mental Hygiene, (18) Pedagogical Seminary, (19) Psychoanalytic Review, (20) Psychological Review, (21) Psychological Bulletin, (22) Psychological Monographs.

ular factor that might cause disagreement was the tendency for some authors to label their studies "experimental" when they were quite obviously statistical. Such reports were not included in this summary, nor were a few lengthy theoretical articles supported by meagre and incidental experimentation.

Journals contributing most to experimental studies of learning and memory.—Table I indicates the percentage of the total number of pages of experimental material dealing with learning and memory for the period 1925-1930 which was contributed by each of six psycholog-

TABLE I

PERCENTAGE OF THE TOTAL NUMBER OF PAGES DEALING WITH EXPERIMENTS ON LEARNING AND MEMORY CONTRIBUTED BY DIFFERENT JOURNALS

Journal	Per cent
Journal of Experimental Psychology	19.6
Journal of Comparative Psychology	19.5
Pedagogical Seminary	19.4
Archives of Psychology	13.6
Journal of Educational Psychology	9.3
American Journal of Psychology	6.7
Other sixteen journals	11.9

ical journals. Of this total number of pages the Journal of Experimental Psychology, Journal of Comparative Psychology, and Pedagogical Seminary contributed more than nineteen per cent each. The six periodicals listed were responsible for approximately ninety per cent of the work of this type reported in English. But slightly more than ten per cent was scattered through the other sixteen publications.

Trend for the six year period.—With respect to the percentage of pages devoted yearly to the type of study under consideration it appears that interest has been on the increase for the last six years. As is represented in Table II, with the exception of a slump in 1929, there has been a more or less constant tendency to devote more attention to experimental studies of learning and memory.

TABLE II

PERCENTAGE OF THEIR TOTAL NUMBER OF PAGES DEVOTED TO EXPERIMENTAL STUDIES OF LEARNING AND MEMORY BY TWENTY-TWO JOURNALS FOR A SIX YEAR PERIOD

Year	Per cent
1925	9.7
1926	11.9
1927	16.6
1928	20.5
1929	15.1
1930	26.2

Number of subjects used per experimental group.—Attention has been called frequently to the tendency for drawing conclusions from studies using too few subjects. However, the *total* number of subjects used in any experimental program is of little consequence. The important consideration is, obviously the number of subjects used per experimental group. The statement "These results are based upon the use of more than sixty rats" becomes relatively meaningless when further investigation reveals the fact that these sixty were divided into six groups of ten each. In view of this consideration, Table III shows the number of subjects per group, and gives for each year the percentage of the total number of groups within certain class limits.[2] It is evident that much improvement is possible with respect to this aspect of experimental technique, nor does it appear that much progress has come about in the last six years. More than twenty-three per cent of

TABLE III

PERCENTAGE OF THE TOTAL NUMBER OF EXPERIMENTAL GROUPS USED EACH YEAR WHICH FALL WITHIN CERTAIN CLASS LIMITS.

	Number of individuals per group								
Year	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81 up
1925	4	22	23	7	6	8	1	9	22
1926	25	31	19	6	1	10	1	0	7
1927	20	23	8	8	9	1	2	7	24
1928	30	12	14	6	1	7	6	2	20
1929	34	15	13	6	12	1	3	3	12
1930	29	27	24	5	6	3	1	1	4
Mean	23.7	21.7	17.0	6.4	5.7	5.0	2.3	3.7	14.8

the groups used for the six year period numbered ten or less. It would seem that such studies are relatively useless for comparative purposes. In quite a number of studies college classes were used for research purposes with the apparent implication that any two classes were sufficiently equated for experimental purposes. This assumption is questionable. The whole matter of the equation of experimental and control groups is quite unsettled, especially in the field of infra-human study. Researchers using animal subjects rarely make an attempt toward preliminary equation of groups, even though this precaution is apparently necessary in the case of highly inbred white rats.[3] Labeling conclusions tentative does not seem to be sufficient justification for the use of groups which are compared without being subjected to some sort of preliminary equation. Such studies merely serve to agitate

[2] Even though some authors described their procedure so inadequately as to make it impossible to get data with respect to size of groups, there are still more groups represented in Table III than there were studies reported. This is due to the fact that many single investigations employed as many as six different groups.

[3] Corey, Stephen M., Equating groups in comparative experiments, Jour. Comp. Psychol., Vol. 10, pp. 282-294, 1930.

further those who have already noticed a measure of inconsistency in psychological results.

Kind of subjects used in experiments on learning and memory.—Granting that the ability to learn is characteristic of all animal life, and for such an assumption there seems to be considerable evidence, it is of interest that so few studies have been reported upon subjects other than vertebrates. One who wishes to approach the problems of learning phylogenetically must progress very sketchily until he reaches the fishes. Table IV partially summarizes the present status of affairs with respect to this factor by giving the percentage of the total number of learning and memory studies which were concerned with humans, rats and mice, and all other animals. The majority of the work dealt

TABLE IV

PERCENTAGE OF THE TOTAL NUMBER OF LEARNING AND MEMORY STUDIES DEVOTED TO DIFFERENT ANIMALS.

Subjects	1925	1926	1927	1928	1929	1930	Mean
Humans	68	51	56	50	56	71	58.7
Rats and mice.....	23	19	33	34	40	25	29.0
All others	9	30	11	16	4	4	12.3

with humans with the almost entire neglect of all phyla except the vertebrate. Less than one per cent of all experimental investigations of learning and memory ability were performed on invertebrates. There appears to have been no particular trend for the six year period with respect to the type of subjects used.

Age of the human subjects used.—Theoretically, the problems of learning at any one developmental level are neither more nor less important than those of any other. For an all inclusive and systematic psychology of the growth of human learning ability it is essential that there be at least a large number of studies for each age. That this situation does not prevail has frequently been noted. There are many studies of the learning and retention of college and graduate students, but experimental investigations of the ability of pre-school and primary children are relatively scarce. In view of the great practical value of such studies in connection with the school, their rarity is even more to be lamented. Teaching methods are more often based upon theories of learning and memory discovered and developed through experiments on animals and adults than upon a keen understanding of the same processes in children. Table V gives the percentages of the total number of experimental studies which were concerned with human subjects at the different age levels. The limits of the age groups cited are arbitrary, but are never-the-less most consistent with the designations used

TABLE V

PERCENTAGE OF THE TOTAL NUMBER OF HUMAN STUDIES PERFORMED ON DIFFERENT AGE GROUPS.

Group	1925	1926	1927	1928	1929	1930	Mean
Pre-school	6	12	16	6	11	9	10.8
Grades I-IV	21	8	5	12	4	2	6.1
Grades V-VIII	21	5	10	20	6	8	11.7
High School	3	13	4	11	15	10	9.3
Adults	59	62	65	52	63	71	62.1

in the studies reported. Children are certainly neglected. More than sixty-two per cent of the studies conducted were performed on adults. Grades V, VI, VII, and VIII came next and the four lowest grades last.

Summary. The following statements summarize the tables:

1. The Journal of Experimental Psychology, Journal of Comparative Psychology, Pedagogical Seminary, Archives of Psychology, Journal of Educational Psychology, and the American Journal of Psychology contributed 88.1 per cent of the experimental literature dealing with learning and memory during the years 1925-1930 inclusive.

2. There appears to have been an increase in the amount of attention devoted to such studies during the period under consideration.

3. Of all the groups used in experiments on learning and memory, 23.7 per cent included less than ten individuals. Few precautions were taken to equate experimental and control groups in infra-human studies.

4. Of all the different kinds of subjects used, 58.7 per cent have been human, with less than one per cent devoted to the invertebrates.

5. Of those studies dealing with human subjects, 62.1 per cent involved the use of adults whereas but 17.8 per cent were concerned with school children.

SYMBOLIC GESTURES IN THE CLINICAL STUDY OF PERSONALITY

BY

MAURICE H. KROUT

Crane Junior College, Chicago.

LABORATORY VERSUS CLINIC

There are two approaches to the scientific study of human subjects: the clinical and the laboratory. Though both methods have made important contributions to psychology, the clinical has often been criticized by those dedicated to the laboratory method of approach. Criticism has sometimes taken the form of vituperative comment [1], more often of benevolent toleration [2], and most often of sublime indifference [3]. In general it has been directed at one or another of the following points, namely, that the loosely defined concepts of the clinical psychologist can not be compared to the more accurate concepts of the laboratory man; that the procedure of the clinic is one of trial and error as compared to that of the laboratory, which is precise and definite; that the clinician is in search of motives of a basic, permanent nature, while the laboratory man is satisfied with the study of stimuli and responses which are immediate, determinable, and possible of demonstration; and finally, that the clinic treats facts historically or descriptively, while laboratory research aims at laws and generalizations.

Every psychologist knows that an experimental laboratory is a place where standardized results are sought through tests performed under controlled conditions. The clinic on the other hand is known as a place where the results of experimental procedure find their application; but it is not advertised as the place where, in the observation of functioning personalties, experimental problems are generally born. Any laboratory which attempts to solve problems conceived apart from clinical situations is doomed to sterility. Conversely, any clinic which does not defer, wherever possible, to the special equipment of the laboratory for the verification of its hypotheses is, to that extent, liable to error.

Yet the clinician can not always refer to the laboratory for verification of observed variations through standardized procedure. In the course of his practice he meets phenomena of behavior and structure which, detached from their setting, change their meaning. If repeat-

edly observed in the course of clinical work, such phenomena reveal a meaning which, in an empirical way, suffices for the clinician. It goes without saying that, were it possible to determine their nature in a laboratory study, these phenomena would possibly increase in definiteness, but they would not be expected to serve as substitutes for clinical procedure. All the tests of a medical laboratory—gastric content, leucocyte count, or whatever—will not, when taken alone, diagnose a case of appendicitis; and all the tests of endurance, motor control, imagination, emotion, or intelligence will not disclose a somatic compensation, an autistic phantasy, or persistent nightmares as adjustive reactions of unsuccessful individuals.

Analysis and Synthesis

Both the clinic and the laboratory then seek to observe and interpret mental states and behavioral patterns of human individuals. The laboratory does so through the manipulation of special sets of data under special conditions. This implies isolation, repetition, and systematic variation to the end of obtaining partial correlations of one sort or another [4]. The clinic does so through the identification of all facts obtained with the organism acting as a unit. This means the projection of every datum against a background of developmental detail, and the correlation of experimental results and clinical observations with the trends revealed in this background. The laboratory's contribution is that of analysis; the clinic's that of synthesis.[1]

Synthesis implies creativeness, for the product of synthesis is always something new and different from the parts that are put together; and the creative savors of subjectivism. Hence the clinical psychologist has been accused of being more of an artist than a scientist. His avowed interest in motivation instead of in explicit S-R units is sometimes given as added proof of his "artistic bias". As a matter of fact, in the study of the dream-aspect of personality by association techniques, for example, the stimulus-response relationship is as much in evidence, on a verbal level, as it is in the study of behavior by the chronoscope or kymograph on a motor level. It is true that clinical results do not always permit of quantification, but a good deal of biological and chemical knowledge (tropistic phenomena, stereoisomerism, etc.) does not lend itself to mathematical formulation.

It is the laboratory scientist who is in a dilemma with reference to the matter of subjectivity and objectivity. In treating facts as he does he is often confronted with the need of deciding in favor of suc-

[1] The clinic may employ analytical techniques for phases of behavior which have not gone through the laboratory stage of development, but its aim is always to reduce procedures of *this* type to the laboratory level as soon as possible.

cession as against impulsion, of extension as against perception, of position as against imagery. Under isolated, controlled conditions such a choice is imperatively necessary. The clinician however is not so afflicted. To him, in the light of the total picture afforded by a given case, subjective evidence—culled from the realm of feeling and perception—has validity only insofar as it is borne out by evidence, both objective and subjective, obtained from other sources. Thus does the subjective find its place alongside the objective in a verifiable sequence of events.

Tests and Techniques

At present the diagnosis of personality rests on a good deal of standardized laboratory evidence sufficiently reliable to be used with confidence in clinical practice. The general intelligence tests (Binet, Otis, National, Army Alpha, etc.), vocational skill tests (Stenquist, Seashore, etc.) tests of emotional stability (Pressey, Thurstone, etc.), self-expression tests (Allport, Rorschach, etc.), and controlled association tests (Kent-Rosanoff, Wells, etc.) represent procedures to which the clinical psychologist must resort with greater or less frequency in the course of his work [5].

There is a group of procedures independent of those listed, which are as yet unstandardized and probably impossible of standardization, on which the clinician must also depend. Among these are general observation, systematic interview, and free-association techniques of the continuous variety. It is through these that the object-orientations of the individual in the fields of sex, religion, work, and recreation can be obtained. Considerable light is thus also thrown on his social-accommodation patterns: his attitude toward other people, toward friend and foe, toward "society in general", etc. His self-regarding attitudes, his insight into his own shortcomings, capacities, and failures will also be, to some extent, revealed by these procedures.

There is a vast field of human activity, as yet little known or indeed even observed, which can be used constructively in personality study. This is the field of gestural responses. I have elsewhere devoted considerable space to these mechanisms of conduct, and I have succeeded in listing one hundred and sixty distinct manifestations of this sort [6]. My list by no means exhausts all the manifestations observable but it is suggestive enough to furnish a guide to their observation and interpretation in clinical practice.

This is the field of phenomena that should yield data diagnostic of somatic compensations and autistic reveries of various kinds. Such gestures, for example, as clearing one's throat, forced coughing, and

convulsive spitting—present where there seems to be no specific or understandable objective stimulation which would throw light on their appearance—challenge the attention of the student of human behavior every day. They may be observed occasionally during the discussion of socially tabooed topics in ordinary or formal discourse. Yawning, when there is no need for sleep, wetting one's lips when there is no special advantage or evident meaning in that movement, opening and closing objects, shifting one's eyes, and back-stepping are again forms of gesturing indicative of various residua of conflict situations. Wiping objects unnecessarily, bringing the index finger to one's lips, scratching one's head or glancing at one's finger nails, pushing up one's spectacles, leaning against a wall, fixing one's hair, or wiping one's nose or lips—not to speak of some very much more involved gestures and postures—are all forms of compensatory expression of the greatest value in clinical study.

Gestures as Clinical Material

The special distinction of the gestural approach lies in the fact that movements observed are objective in the sense of having both extension and succession. As such they should lend themselves to laboratory study. But the laboratory method does not fully meet the needs of the case. Even if the movements in question could be isolated under standardized conditions, they should not be interpreted without the aid of the clinic. The interpretation of these movements and tensions depends on the study of genetic trends in the biography of the individual (with special attention to emotional fixations), the careful observation of situational cues with which the autistic phenomena are associated, and a modified application of Jacobson's technique of "autosensory examination" [7]. By this technique the subject is taught to reinstate the gestures and postures observed and, on being given the cues to which he had evidently responded, to verbalize the meanings evoked. In this way obscure symbolic material, obscure in spite of its objectivity, is given meaning and converted into valid clinical data.

The gestures and postures described are sufficiently frequent in all individuals and promise sufficient uniformity to deserve attention in personality diagnosis. Of course it is not suggested that the clinical psychologist must define all the subtle nuances of behavior displayed by his subject. Nor is it suggested that only subtleties of behavior should be used in the clinical survey of personality function. The study of these substitutive responses must be regarded as merely one of the methods open to clinicians in the synthetic study of human material.

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PSYCHOLOGY OF ARITHMETIC IN THE LIGHT OF RECENT EXPERIMENTATION

BY

EDWARD F. POTTHOFF

University of Illinois, Urbana.

A large number of experiments have been conducted in recent years in the field of arithmetic. In 1925 Buswell and Judd published a monograph containing a summary of all scientific investigations relating to arithmetic which had appeared up to that time.[1] This summary has been kept up to date by the publication each year of a supplement to the monograph—the monograph, together with its supplements, containing a total of 584 titles. In the short time which is at my disposal it is obviously impossible to deal with all of these studies. This paper is restricted to a small number of experiments which deal with the fundamental operations, especially addition and subtraction. An attempt is made to give a brief summary of these investigations and to interpret them in terms of the psychology of arithmetic.

Since 1913 a number of studies have been made to determine the relative difficulty of the various number combinations. These studies used a variety of methods of determining difficulty, some of them employing the number of errors made by large groups of pupils in giving a combination, others measuring the time required by pupils to give the answer for each combination, and still others determining the difficulty of learning the combination. Probably the most outstanding of all of these studies is the one reported by Clapp[2] in 1924, using the first of the methods just mentioned.

Although some of these investigations do not agree very closely as to the degree of difficulty of the various combinations, they all show that some of the combinations are much more, or much less, difficult than others, and especially that the difficulty of a given combination is not necessarily the same as that of its reversal. For example, Clapp's study showed that 3 plus 8 was much more difficult than 8 plus 3, and that 5 times 6 was more difficult than 6 times 5. Similar relationships were found in the case of subtraction and division. The combination 11 minus 9 was much more difficult than 11 minus 2, and 56 divided by 8 more difficult than 56 divided by 7. The studies show that there

[1] Buswell, Guy T., and Judd, Charles H., Summary of Educational Investigations Relating to Arithmetic, Supplementary Educational Monographs, 1925.

[2] Clapp, Frank L., The Number Combinations, Bureau of Educational Research Bulletin, No. 1 and No. 2, University of Wisconsin, 1924.

is some tendency for direct and reverse combinations to resemble each other in difficulty, but they are by no means identical. In other words, a child may know a number fact in one direction but not in the reverse direction.

The results of these investigations upon the relative difficulty of the number combinations have been used by some educators to explain the psychology of arithmetic in terms of the bond theory of learning. It was inferred that each combination had to be reckoned with as a separate entity and taught as such; each was regarded as a bond which had little or no connection psychologically with any other; that is, the learning of one number fact had little or no facilitating influence upon the learning of another.

This interpretation has had a definite influence upon the construction of textbooks and upon methods of teaching. When each of the digits between 0 and 9 inclusive is added to itself and to each of the remaining nine digits, a total of 100 addition facts results. The early writers of textbooks assumed that it was unnecessary to teach the combinations involving zero, and that a child who knew a combination in one direction also knew the reversal. Consequently they provided for the teaching of only 45 addition facts. Similar assumptions and practices were followed in the case of the other fundamental processes. The line of investigation already referred to, however, led to the assumption that each number fact had to be learned separately and specifically. As a consequence modern textbooks provide for the teaching of all of the combinations. The earlier psychology assumed that it was unnecessary to teach certain number facts because of their relationship to others which were taught; the later view assumed that in the child's mind, at least, there were no relationships among the various number facts, and that, therefore all of them would have to be taught, and that they were to be taught as if no inter-relationships existed or could be supplied.

It is this later view which we shall now attempt to examine in the light of recent experimentation. Is it true that from the point of view of the child there are no relationships among the number facts? The results of three experiments which bear upon this question will be summarized at this point.

The first study to be referred to was reported by Buckingham in 1927.[8] In each of seven schools he divided the second grade pupils into two equal groups. One group was taught a list of nineteen addition facts during one week, and the corresponding nineteen subtraction facts during the following week; the second group was taught the same thirty-eight facts, but together rather than separately. Further-

[8] Buckingham, B. R., Teaching Addition and Subtraction Facts Together and Separately, Educ. Res. Bull. 6, pp. 228-229, 240-242, 1927.

more, for the second group the facts taught at any one time were selected so that they were related anl constituted a set. One such set, for example, included the following combinations: 1 plus 6, 6 plus 1, 7 minus 1, and 7 minus 6. The same amount of time and the same methods of teaching were used with both groups of pupils. At the end of the experiment a test over the thirty-eight combinations was given to both groups. In six of the seven schools the results on this test were very strongly in favor of teaching the combinations together rather than separately. In the seventh school the procedure followed by the teacher was so irregular that the results should hardly be considered.

The second experiment was reported in 1930 by Beito and Brueckner.[4] They used a total of 93 second-grade pupils found in three schools, and employed only those addition combinations which are reversible. They had the teachers spend three weeks teaching the direct combinations only, not their reversals. Three different methods of teaching the addition facts were employed. The pupils were tested as to their knowledge of both the direct combinations and their reversals at the beginning and again at the end of the period of instruction. In this way it was possible to determine what number facts a pupil learned during the experiment. The results of the tests showed that the pupils gained slightly more on the reverse combinations, which had not been taught, than on the direct combinations, which had been taught. The experimenters stated, "Although the reverse combinations were never mentioned during the study except in the pretest and the final test, the pupils in some manner made the adjustment to the reverse combinations to such an extent that a very large percentage was learned in the reverse combinations. This result was consistent throughout all classes and for the different methods of presenting the combinations."

The final experiment which is of interest in this connection was reported by Olander in 1930.[5] He employed a total of 37 sections of second-grade pupils taught by 26 different teachers, and continued the investigation over a period of 17 weeks. During the first 11 weeks the pupils were taught a list of 55 selected combinations in addition and an equal number in subtraction. In order to understand the selection of the combinations taught we must recall that the 100 addition facts include 45 pairs of reversible combinations. Six of these pairs were taught in both direct and reverse order, six remained entirely untaught, and the remaining ones were taught in either direct order or in reverse

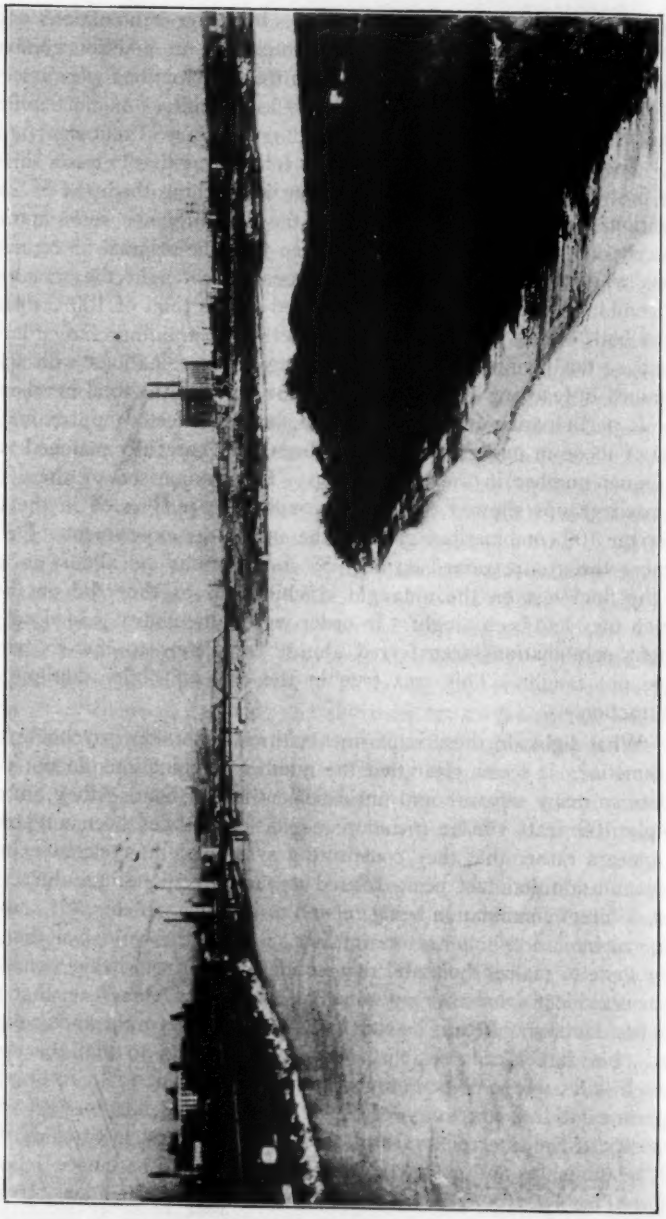
[4] Beito, E. A., and Brueckner, L. J., A Measurement of Transfer in the Learning of the Number Combinations. Twenty-ninth Yearbook, National Society for the Study of Education, pp. 569-87, 1930.

[5] Olander, H. T., Experimental Determination of Transfers in Addition and Subtraction, Doctor's Thesis, University of Chicago, 1930.

order, but not in both directions. The subtraction combinations which were taught were those which corresponded to the addition combinations. In both addition and subtraction the combinations were selected in such a way that those not taught were as difficult as, or more difficult than, those which were taught, according to Clapp's difficulty values.

The same teaching procedure was followed with all classes during the first eleven weeks of the experiment in teaching them the 55 combinations already referred to. During the remaining six weeks approximately one-half of the classes continued with the original 55 combinations while the other half of the classes were taught the remaining 45 combinations. All classes were tested on the total of 100 combinations both before and after this last period of training. In order to compare the results obtained in teaching 55 combinations with those obtained in teaching 100, Olander did not consider the total number of pupils participating in the experiment, but he selected approximately 300 of those in one group who had been very carefully matched with an equal number in the other group. The comparison of these two equated groups showed that both groups did equally well in the test over the 100 combinations given at the end of the experiment. Furthermore the group trained on only 55 combinations did almost as well in the final test on the untaught combinations as they did on those which they had been taught. In order words, the ability gained on the taught combinations transferred almost completely to the 45 which were not taught. This was true in the case of both addition and subtraction.

What light do these experiments throw upon the psychology of arithmetic? It seems clear that the number combinations do not constitute so many separate and unrelated entities or bonds—they are not simply 100 feats of the memory—as has sometimes been supposed. It appears rather that they constitute a system of interrelated experiences, an addition fact being related to the corresponding subtraction fact, a direct combination being related to its reversal, etc. Of course, these interrelationships are not, at first, clear to the child, but that he may come to realize them and that he may profit from being aware of them is evident from the experiments. It follows, therefore, that the number facts should not be taught as so many separate and isolated items, but rather as a system of interrelated facts so that the pupil himself will come to regard numbers in this systematic fashion. Further experimentation is necessary, of course, in order to determine just what elements of the interrelationships shall be emphasized in teaching, but that relationships and not merely separate facts shall be taught follows unquestionably from the experimental evidence which is already available.



ILLINOIS RIVER AT PEORIA (Courtesy Peoria Star)

(Courtesy Peoria Star)

Illinois River at Peoria

PAPERS IN ECONOMICS

Report of the Section Chairman

The Economics Section of the Academy was created as a result of suggestions received from members in several of the fields represented in its membership. It was felt that some opportunity should be given each year for the consideration of the economic application of some of the scientific problems. Accordingly the 1931 session of the Academy witnessed the inauguration of the Economics Section under rather favorable conditions. Taking advantage of the fact that the meeting was to be held in Peoria the chairman arranged a program which would appeal to the citizens of that community and which seemed should result in some value to that part of the State. *"Some Economic Problems of the Illinois River Valley"* was selected as the main subject for the session. With the cooperation of the Peoria Chamber of Commerce and the Peoria Rotary Club a joint meeting was held with the latter organization at the Jefferson Hotel. As a foundation for the subsequent more practical papers to be presented in the afternoon, Professor E. L. Bogart of the University of Illinois, President of the American Economic Association, was asked to speak at the joint session on *Economic History of the Illinois River Valley.* This meeting was attended by about two hundred people. The attendance at the meeting following the joint luncheon session was about sixty or seventy-five. The brief business session resulted in a vote to perpetuate the Economics Section and by authority of the session the chairman appointed a committee to perfect the organization and to appoint a chairman for 1932. The committee thus appointed consisted of Dean Charles M. Thompson, E. L. Bogart, F. A. Russell, F. E. Lee, and C. L. Stewart. The Committee selected Professor E. L. Bogart as chairman for next year.

(Signed) H. T. Scovill, *Chairman.*

ECONOMIC HISTORY OF THE ILLINOIS RIVER VALLEY

BY

ERNEST L. BOGART

University of Illinois, Urbana

The topic which has been assigned to me is a large one, and in order not to wander too far afield, I shall confine myself to certain aspects of the economic history of this river valley, especially those connected with the development of transportation. The men who first settled this country were pioneers, and I think we do not always realize the hardships which the early pioneers experienced. The people who left the Atlantic seaboard, then the industrially and culturally most advanced section of the United States, and moved out west undoubtedly did so in order to improve their economic position. But when they did so, we must remember that they cut themselves off from everything which they held dear. The journey from, say, Connecticut to Illinois was more toilsome and expensive than the journey, three times as long, from Europe to Connecticut, and it constituted more of a break with home and friends.

After the first pioneers had reached this Illinois country, then practically untenanted and undeveloped, they built homes and proceeded to raise food and develop the resources. But, cut off as they were from the older sections of the country by poor and inadequate means of transportation, they could neither obtain supplies nor market their own surplus and were almost wholly dependent upon their own production. They were true backwoodsmen. Because they were poor, they lacked most of the things which we accept as a matter of course today, both household equipment and industrial and agricultural tools; and because they did not have intercourse with the East or with Europe they were unable to buy these things by selling the products of their farms. As a result they carried on a self-contained economic existence, but were unable to raise their standard of living. As producers they lacked market facilities and as consumers they lacked the opportunity of getting the things they needed. The only method by which they could extricate themselves from this dilemma was by improving the means of transportation. This was the essential condition of the opening up the interior of the continent. Always important, it became absolutely vital after the westward movement carried the population across the Appala-

chian mountains and away from the accustomed markets on either side of the Atlantic ocean.

Let us note briefly the position of the earlier settlers in the Ohio Valley. For them there were two routes to markets: one was overland to the East and the other was down the Ohio and Mississippi rivers to New Orleans. The overland route to Philadelphia or Baltimore, through one of the mountain passes in the Appalachian chain, was long and difficult and over it only articles of considerable value and small bulk could be profitably transported, such as furs and ginseng. Some hogs and cattle were also driven east, but in general this route was unsatisfactory. The other route, down the rivers, was easier and cheaper. Products could be loaded on rafts, barges, arks, and other water craft and floated downstream to New Orleans. Goods would be accumulated during the winter in the upper valley and, when the spring freshets made it possible to float them down, whole flotillas of vessels would cut loose and start their journey. The market at New Orleans, small and precarious at best, was soon glutted and the returns were frequently very small. The farmer of one hundred years ago got as little for his crops as his descendent does today.

Illinois, situated far to the west, was able to avail itself of only one of these routes, that down the Mississippi. The settlers in this territory had therefore a very limited outlet for their products. This was the situation until 1814 when the first steamboat was built at Pittsburgh and proceeded downstream. But although the boat had gone down it could not return up the river against the swift current. Not until 1816 were sufficient improvements made in boilers, paddle-wheels, and other parts, so that the steamers could move upstream by their own power. In that year, the *Enterprise* steamed up the river from New Orleans to Cincinnati, and a new epoch in western transportation was begun.

The advent of the steamboat spelled a new era of prosperity for this part of the country. River towns in Illinois now came into their own. Cairo was pictured as a commercial metropolis central to all the Union, at whose wharves ocean-going ships laden with the produce of Europe and the West Indies would discharge their cargoes—the Venice of the New World. Alton showed the steadiest commercial development during the 'thirties and was expected to surpass St. Louis. In 1826 Peoria was laid out along the Illinois River and four years later the first steamer arrived here. In 1831, seventeen steamboats landed their cargoes at the wharves of the village, which was growing fast and promised to become one of the important towns of the west. In 1838 Peoria had daily stage connections with Springfield, and three times a week stages ran between it and Galena, Ottawa, and Rushville.

But those parts of the State not touched by rivers, remained undeveloped and untenanted. The northern part of the State was more or less a wilderness. Peoria was really an outpost on the northern fringe of settlement in Illinois. Beyond it were to be found only a small settlement at the mouth of Chicago River and another at Galena near the lead mines. In all this territory, between Peoria on the south to Wisconsin on the north and east to the Indiana border, the population in 1830 was only 1,310. The movement of traffic was not sufficiently great as yet to warrant the building of means of transportation in addition to the natural waterways. These served adequately the needs of the sparsely settled and scattered Illinois settlements. The movement for further improvement in transportation facilities had to come from some more densely settled eastern state, and the necessary impetus was furnished by New York.

In 1825 the Erie Canal was opened and at once the complexion of the east-west trade was changed. A through water route was provided by which products could be shipped between Ohio, Indiana, or Illinois, and the Atlantic seaboard. This canal had profound and revolutionary effects. New York City grew as never before and soon far outstripped Philadelphia and other eastern seaports. At every point on the canal where a river touched it a new town sprang up, as at Rochester, and these cities grew rapidly. But the greatest effect was on the west, especially along the Great Lakes. The western farmer profited in two ways: the goods he bought from the East could now be had at one-half or one-third the former prices, and he was able to sell his agricultural products for double or treble what he had formerly obtained. If these benefits were to be distributed to the settlers in the central or southern parts of the western states, away from easy access to the Great Lakes, it would be necessary for these states to build their own canals. This fact was quickly appreciated and Ohio led the way in 1835 with the construction of the Ohio Canal, running from Cleveland to Portsmouth on the Ohio River, and followed soon after with the Miami and Erie Canal. Indiana built a long canal clear across the state, and Michigan and Wisconsin projected improvements far beyond the needs or financial capacity of their scanty populations. Illinois was the last state to enter the field of canal building, with the Illinois and Michigan Canal.

Illinois was late because most of her population had settled in the southern half of the State, which was adequately served by the river traffic. By 1835, however, the northern section had a considerable population, which became increasingly insistent upon connection with Lake Michigan and the advantages of the through water route to New York. The General Assembly responded to the pressure by passing the act of

February 10, 1835, providing for the appointment of a canal commission and the issue of a state loan. The federal government was also persuaded to make a grant of public land for five miles on either side of the proposed route. On July 4 of the following year the new declaration of independence of transportation was celebrated with appropriate ceremonies with the beginning of the Illinois and Michigan Canal at Canalport on Chicago River.

The route of a canal across the State of Illinois was clearly marked by nature, and had long been recognized—by Marquette, by Gallatin, and by later writers. When the State was admitted to the Union in 1818, the northern boundary had been pushed sixty-one miles to the north in order that this natural route might lie wholly within the State of Illinois. As an engineering project the way was clear. But from a financial standpoint a more inauspicious time could not have been chosen. Several difficulties at once arose. As is usual in such undertakings the cost of construction had been underestimated and the initial estimate was revised several times, and always upward. The financial panic which came in 1837 proved a very serious blow to the prospects of an early completion of the canal. Most of the money was borrowed from England and as the financial situation became worse, especially after the repudiation of their debts by certain of the states, it became impossible to obtain additional funds from this source. An appeal was made to the English bondholders to advance sufficient money to complete the canal, since the unfinished project was utterly worthless. This they finally agreed to do on condition that the canal be managed by trustees of their selection until they were repaid. As this was manifestly to the advantage of all concerned this arrangement was made, and the canal was thus administered for twenty-three years or until the canal debt was expunged in 1871.

The Illinois and Michigan Canal was completed in 1848 and at once proved a great success. In endeavoring to estimate its economic importance we must, however, distinguish at least three different periods in the history of the canal. The first one, to 1848, was one of construction and was marked by land speculation and rapid settlement. The population in the district between Peoria and Chicago grew from about 20,000 in 1835 to 125,000 in 1850. Chicago, which was only a trading post in 1834, had 20,000 inhabitants when the canal was opened in 1848. The story of land speculation and the enormous rise in prices is so familiar that it need not be repeated here.

The second period, between 1848 and 1854, was that of the canal's greatest prosperity. We today cannot estimate its value or its importance to the domestic commerce of Illinois at that time. It represented a

tremendous move forward and provided a through waterway across the State between New York and New Orleans. The Ohio and Indiana canals had been handicapped by large lockage and by shortage of water, but the Illinois and Michigan Canal was superior in both these respects. Through the canal came lumber, shingles, posts, and other forest products from Michigan, which found their way as far west as Leavenworth, Kansas. Merchandise from the East and agricultural implements of Chicago manufacture passed in the same direction for distribution to the canal and river towns and by them to the interior settlements. In return the farm products from the regions traversed by the canal and Illinois River, together with sugar, molasses, coffee, and other tropical products from New Orleans found their way through this water route to northern and eastern markets. Its effect on the cities along its route were similar to those observed on the Erie Canal twenty-five years earlier.

A strong impetus was given to the development of Peoria, whose population doubled between 1847 and 1850. During this period 579 buildings were erected, and in the latter year some 1,286 steamers touched at the Peoria wharf. Even more rapid was the growth of Chicago, whose population increased from 20,000 in 1848 to 75,000 in 1854, and whose importance as a commercial distributing point dates from this period. The effect on prices was also significant. Before the opening of the canal wheat sold on Illinois River at 50 cents, whereas the usual price in Buffalo was about $1.20 a bushel. After the completion of the canal the prices of farm products in Illinois doubled and the cost of eastern manufactures and other goods was cut in half.

The third period marks the rise of effective railroad competition and the gradual but steady decline in importance of the canal and river traffic. In 1847, Rock Island and LaSalle Railroad was chartered to run between these two towns in the apparent expectation that it would serve as a feeder to the canal by drawing to it some of the upper Mississippi trade. Four years later the road was extended to Chicago and renamed Chicago and Rock Island Railroad. It paralleled the canal and at once became a competitor rather than a supplement. The passenger traffic deserted the canal for the quicker rail route almost immediately, and soon the freight began to follow. A long but hopeless struggle now began, the outcome of which is familiar to you all. It was not until 1899, however, that the first serious break in canal traffic occurred, but this was followed the next year by a sharp drop and within a few years the traffic was so small that statistics of its amount were no longer collected.

The story of the construction of the Sanitary Ship Canal and of the revival of the Illinois River commerce will be told by others. Permit me to say just a word in conclusion. What shall we judge from this brief survey? There is one thing which I think we may learn, and that is that the transportation problem is never solved. Most of us came here by automobile. One of your speakers has just mentioned the airport to be built at Peoria, and the next speaker will discuss the Inland Waterways Corporation. We never stand still. Illinois and Michigan Canal, with Illinois River, was a phase of the economic development of this river valley, and although we have left that far behind he would be a bold man who would speak dogmatically of the future. We must be open-minded as to what constitutes good transportation. Did the canal pay? That is hard to say, as it depends somewhat upon who makes up the statistics, but an accountant would undoubtedly answer in the negative. But from the broader social point of view I should say that the State made a good investment at the time it built this canal. It played its part, served its turn, and today has passed into history. From this history let us learn the lesson that it offers.

COORDINATION OF RAIL, WATER, AND MOTOR TRANSPORTATION

BY

MAJOR GENERAL T. Q. ASHBURN
Inland Waterways Corporation

No well informed man, except for political purposes, is advocating the extension of any of our interior waterways solely as navigable streams, unless such extension can be proven to be in accordance with sound economics and sound engineering principles.

Congress has announced its policy to be to promote, encourage, and develop waterways, and to foster and preserve in full vigor, both rail and water transportation.

It has created the Inland Waterways Corporation as its pioneering and demonstrative agency to prove that, through proper coordination of rail, water, and motor transportation, there will result for the people a better and cheaper form of transportation, and that from the results of such cooperative efforts the participating carriers will receive a living revenue.

When this highly desirable end has been attained, when the operation of common carriers upon our interior streams has become attractive and financially profitable for private capital, then the government will sell its facilities, step out of the picture, and let private capital carry on, under such conditions that water transportation shall never again be throttled.

The problem confronting the people of the United States is this:

We have hundreds of millions of dollars—nearly $1,500,000,000—invested in our harbors and navigable waterways, and we have been appropriating annually vast sums of money to continue making navigable streams in the hope that by their utilization there will result a cheaper means of transportation whereby the whole country will profit. This vast project has been only partly completed, and it will require a comparatively small sum to complete that part of it which has been found to be in accordance with sound economics and sound engineering principles. Upon its completion we may look with certainty to the fact that through cheaper and better coordinated water-rail-motor service there will result a system of transportation better and cheaper than any single

system, affording every one a real return upon the money which he has invested in the form of taxes.

These savings, inherent in water transportation, will be available not only to those communities fortunately located upon our navigable streams, for when this coordinated system of joint routes and rates is fully developed in accordance with the Denison Act, the shipper in the interior will receive the same savings in cents per hundred pounds through joint rates as the man located on the river. The general principle governing in the application of the water saving to the joint rate is to apply the water saving between the river ports to the all-rail rate between the point of origin and destination, and then to establish a joint route via the Federal barge lines (by rail and water, or by motor and water), cheaper by the water saving than the all-rail or all-motor rate.

This is exactly what we propose to do for every interior shipper, and yet the opponents of waterway development and the operations of the Federal barge lines propose that we should abandon this vast network of waterways, already partially completed, charge it to profit and loss, and admit that our whole policy of 110 years has been a colossal failure, instead of spending the money necessary to make the system complete. It is submitted that no business organization, no combination of capital would abandon any such sum as $1,500,000,000, already spent to complete seven-eighths of a project which until completion is of little value, when by the appropriation of the additional one-eighth necessary to complete the project there would result a reasonable return upon the whole investment.

Whence comes this apprehension on the part of the Securities Owners Association that the development of our waterways may prove destructive to an adequate return on the investment in many railway systems, this belief that the savings in freight charges to the users of the waterways are more than offset by hidden costs borne by the taxpayer.

These, my friends, are the red herrings drawn across the trail to distract your attention from the fact that, through the utilization of such of our interior waterways as are navigable in connection with railways, the people of the United States *are* getting what they have taxed themselves for a hundred years to get, cheaper transportation. If there be any one thing likely to affect the value of your rail securities to depress them, it is the constant harping by certain individuals that the railroads are bound for destruction unless they can be delivered from their competitors; amongst which they include waterways. These voci-

ferous promulgations of the idea that the railroads are headed straight to perdition do you more harm than good.

The people, as shippers and as receivers, and as users of commodities shipped, are not interested in academic discussions of the relative costs per ton mile of rail or water or motor traffic; they are not vitally interested in statistical nebulae disseminated from unknown or biased sources; they are vitally interested in whether the transportation for which they pay is cheaper and better by one form than another; and you as "Owners of Railroad and Public Utilities Securities," are not interested in these statistical nebulae; what you are interested in is the effect the development of water transportation will have upon your securities. Hold these facts in your mind, get the problem squarely before you, and then let us discuss it amicably without regard to any gas attack designed to befuddle you.

Every new country passes through four stages of transportation; transportation by water, by paths and roads, by rail, and finally the stage of coordination and cooperation—the stage through which we are now passing.

Each of these stages follows as naturally as day follows night, each performs its function satisfactorily considering the conditions involved, each in the order named inevitably leads to the other; and as a better and cheaper and more satisfactory form appears, the less satisfactory and the more expensive form fights constantly to prevent the people of the United States from enjoying such transportation, and always on the ground that "the existing forms of transportation fill all our needs, and if you allow competition it will destroy our revenue. We are too important to be destroyed or hurt; we have expanded at the people's demand, and it is unfair competition to subsidize some other form of transportation to our disadvantage."

It will be observed that there is no thought anywhere in this argument that the people who have paid and paid to get transportation, who have allowed one form to supersede another (and always by subsidies), have any legal or ethical right to patronize that form of transportation which is of most value to them.

Let us see what this billion and a half dollars of which mention has been made, has been spent to accomplish.

About one-half of it has gone to the construction and maintenance of our harbors, one-third to flood control, and one-sixth for purely navigation purposes.

Out of this sum have been constructed the great harbors of Boston, New York, Philadelphia, and others on the Atlantic, ports on the Gulf,

the Pacific Coast, and the Great Lakes, and this money has been spent as much for the railroads as for any other system of transportation.

In a recent pamphlet issued by J. Hampton Moore, ex-Congressman, ex-mayor of Philadelphia, he says:

"In what position would the Reading Railroad be if the Federal Government should permit the Delaware River to be closed by refusing to make appropriations for its improvement or maintenance? In the first place, the Federal Government would shut off approximately $50,000,000 a year which is collected at the Port of Philadelphia not from the local taxpayers, but from the foreigner who is doing business with the United States. In the second place, without reference to the national influence of the Navy Yard on the river or the millions of tons of commerce that come and go, or the billion dollars worth of industrial business, including employment, done in one way or another on the river for the benefit of the railroads and all other business, commercial and transportation institutions, it would force the Reading Railroad or the Baltimore and Ohio, if it is to take over the Reading, to completely reorganize its business, with a possibility of unemployment the end of which cannot be foreseen."

This example could be multiplied ad infinitum.

Flood control projects cover, to some extent or another, practically every state in the Union, and particularly those of the Mississippi Valley; and the money so spent has been spent largely to protect the very valuable railroad properties lying parallel to, or behind the rivers. What would happen to these if the government ceased to spend money for flood control?

A very considerable proportion of what has been spent for navigational purposes solely, was spent before the advent of our railways, and present navigation has been brought about largely by funds spent for other purposes. Any project for flood control inevitably is bound up with improvement of navigation; and the vast sums of money with which the operators of transportation facilities on our inland streams are charged as subsidies is a palpable hoax. It is a more palpable hoax to attempt to charge these entire costs, as subsidies, to the Inland Waterways Corporation, an agency of the people, owned by the people, created by the people for the sole purpose of demonstrating that our whole national policy of 110 years regarding interior water communications has not been a colossal failure, but was a demonstrably good policy.

When the Inland Waterways Corporation was created in 1924—just about six and one-half years ago—to make this demonstration, there was no hue or cry raised against its operations, because the opponents of water transportation were so immeasurably secure in the belief that interior water transportation was too moribund to be resuscitated, and the whole theory of promoting, encouraging and developing water

transportation, while at the same time fostering and preserving in full vigor rail transportation, seemed too fantastic for utterance. But when this organization was created, when it turned an annual operative deficit of a million dollars a year into an average net operating revenue of about $81,000 per annum, when, during the calendar year of 1930, despite an unprecedented period of depression, a long continued drought of such proportions as to become a national calamity, its net operating income was slightly more than $66,000.00; when the floating equipment upon our navigable streams involved hundreds of private, common, and contract carriers; when the total invested by such carriers aggregated a sum between a hundred and fifty and two hundred million dollars; when, in fact, the Inland Waterways Corporation was demonstrating what it set out to do, then began that insidious but persistent, and finally open, opposition, which has taken the virulent form of misleading the people into the belief that the success of water transportation means the destruction of railways, the lowering of their securities and bonds, and is generally a damnable ogre which should be destroyed. The same arguments which are being advanced are the arguments advanced by the opponents of railways in their early days, and the same arguments now being advanced by the eastern railways in their opposition to a new short rail line between New York and Chicago.

The arguments against completing the project of a main arterial system, with its ramifications extending outward from the main system in the order of their economic necessity (and only when in accordance with sound engineering principles), run about as follows:

1. That hundreds of millions of dollars have been spent to create navigable streams, in the vain hope that cheaper transportation would result from their utilization.

Speaking before the Atlantic Deeper Waterways Association, the then Secretary of War, Mr. Good, said:

"In the early days of our Government, the handling of commerce by means of shallow-draft boats upon streams in their natural state was in many cases the only means of transportation available into the interior of our country. Our people worked their way from the Atlantic Coast to the Rockies, building a nation as they went, the winning of each step forward being made possible by use of all available waterways. Many of our earlier projects provided for channels of but 4 feet, and in some instances of 2 feet and even 1 foot in depth. These depths were adequate to meet the needs of those times, but this is no longer true. Larger barges and boats are now required and the shallow draft channels have become obsolete, except in isolated cases where they are the only available means of communication.

"In computing the total expenditure of the Government on the improvement of waterways of this kind, their cost cannot be charged up as a loss, as they paid for themselves many times over during the earlier years. Our

waterway plan was not built in a day. It was a matter of growth. This was so of necessity, for it would manifestly be a waste of public funds to undertake the improvement of all waterways at one time, regardless of the economic need. The only solution, therefore, was to build those parts of a waterway where the economic situation was such as to justify each section as it was built. However, we are now fast approaching the time when we can visualize the completion of the entire project and when the sums necessary for such completion can be provided without undue strain upon the Treasury."

2. That there is no necessity for such development, as the railroads are amply able to care for our expanding commerce.

Although it is undoubtedly true that the railroads can amply take care of our expanding commerce, it will be at such a tremendous expenditure as to be stupendous.

Between 1920 and 1930 it was repeatedly stated by prominent railway executives that the cost to the railways of keeping pace with our expanding commerce was approximately a billion dollars a year, and railway expenditures between those years approximately kept pace with this estimate. In order to raise this revenue there has been a persistent urge for increased freight rates, and this urge, and its accomplishment to a certain extent, has brought about a most unbalanced and unequitable situation.

The great central west, which we speak of generally as the Mississippi Valley, has been penalized to such an extent by these freight rates that it is decreasing in production, manufacturing, and population.

We, as a people, have gradually reached the sound conclusion that the prosperity of the nation is bound up in the prosperity of its component parts, and that when one section is penalized at the expense of another, when one section is prosperous and another impoverished, that it is the business of the nation as a whole to restore an economic balance.

This economic balance in the middle west can only be restored through the medium of cheap river transportation, in cooperation with rail and motor transportation.

B. C. Forbes, in the Finance Section of the Washington Herald of February 20th, quotes with approval the following letter from a correspondent:

"Whether intentionally or not, the present railroad policy, of giving the best service at the point where there is plenty of competition, is drawing to those points business which will have to be shared with others and is taking away from other points business which the railroads would get 100 per cent."

A manufacturer locates where he can assemble his raw material cheaply, and distribute his finished products cheaply. When these costs get out of line, either for the assembly of raw material, or for the distribution of the finished product, he moves to some place where he can

find these conditions, and always he moves to the lakes, the gulf, the seacoast, or our interior navigable streams. If on our interior navigable streams, he locates at that place where proper terminal facilities for interchange between rail and water and motor facilities exist.

The utilization of Mississippi River and its tributaries is restoring the economic parity destroyed by the diversion of traffic between east and west by the Panama Canal, and by the railroad policy outlined by Forbes, and if we cannot restore that economic parity, then the nation as a whole is bound to suffer.

There is a very vital relation between the prosperity of a city and its environing community. If a small city loses a large manufactory, by removal to some other city, or a large city loses a number of its manufactories, it hurts the agricultural environment by the loss of that much of its market, and throws it into the position where it must reduce its output, or seek other markets where transportation costs put them at a disadvantage; and they may be compelled to sell at a loss, or even lose the market. This condition reflects itself in the purchasing power of the agriculturist, and this limitation of such purchasing power is again reflected in the failure of the city merchant to dispose of his stock promptly, if at all; and further, the railways lose transportation, to their disadvantage.

The reverse is true, as I shall demonstrate.

3. The third general charge is that the utilization of our interior waterways will result in a loss of revenue to the railroads, to their vital injury.

The utilization of our interior streams, as demonstrated by actual experience, does not result in a loss of revenue to the railroads, to their vital injury.

There is a cycle of transportation leading to saturation. This saturation point is reached for any city when the cost of collecting the raw material and distributing the finished product is greater for that particular city than for some other location; and it will inevitably result, as many cities have reason to know, in the abandonment of particular manufactories in that city, and the establishment of the same manufactories in some other more suitably located community, where the transportation facilities are not saturated; and almost always the new point selected is a city on a navigable stream, the lakes, the Gulf, or the seacoast.

Let us examine this cycle as it has worked out in Pittsburgh. The location of the steel manufactories at that particular point was determined by the fact that ore, coal, and other articles necessary to the manufacture of steel could be assembled there more cheaply than any place else at that time.

The establishment of the steel industry drew workers, naturally, who wanted the necessities, the comforts, and the luxuries of life. As the industry expanded, more raw material had to be collected, more finished products distributed, more workers and their families came, each of these causes contributing to an ever increasing demand for transportation. This cycle expanded continuously, until today Monongahela River is carrying annually 26,000,000 of tons and the Pennsylvania Railroad, instead of being hurt, has four times expanded its Monongahela division, which is practically given over to freight handling. Other railroads have similarly expanded. What the river took away from the railroads in its handling of bulk commodities, it returned four-fold to the railroads in the creation of demands for supplies and distribution that could not be handled by the river alone.

When the railroads first entered the transportation field, in spite of the aid granted them by the government, states, counties, communities, etc., through land grants, special privileges, and what not, the financial burden upon them compelled, as they pushed their way ever westward and northward and southward, that they create communities, towns, and cities to furnish them freight enough to pay their expenses of pioneering and expansion, and as unfettered competition sprang up amongst railroads touching the same points by various routes, began that system of rate making which is so involved and intricate, but which resulted in the creation of flourishing communities west of the Mississippi and east of the Rockies. The movement of freight into, and out of the states west of the Mississippi was enormous, and most of the railroads east of the Mississippi profited by it. It is largely the loss of this freight, brought about by the policy of which Forbes speaks, the forcing of competition, with the consequent necessity of dividing business amongst many carriers, which, if normally distributed, would go to single railroads, that is greatly responsible for the present condition of our western carriers. Let us examine a recent example of what occurs when a navigable stream is properly utilized.

What located the great aluminum ore works at East St. Louis, Illinois, employing hundreds of men, and distributing its finished products all over the world? It was the cheap cost of transporting bauxite ore from the British Guianas by ship, thence up Mississippi River by the Federal Barge Lines. This great plant would never have been located there unless the Federal Barge Lines had given a water rate sufficient for the company to compete with Baltimore rates.

Who profits by the location of this plant at East St. Louis? Every railroad which connects with East St. Louis.

How? Through exactly the same cycle as has been described for Pittsburgh. But here nothing was taken from the railroads. A new industry was created by which they profited.

4. The fourth general inclusive charge is that the waterways are subsidized, and that the Inland Waterway Corporation is in unfair competition with the railroads, that the railroads are unduly restricted by regulations, and that they pay part of the water saving.

The truth, is that waterways and railways, properly coordinated and cooperative, are indispensable to each other.

It seems strange to me that the railways should be so bitterly opposed to interior waterways, when this form of transportation is the only form that gives them back more and better traffic than it takes away. There would be more sympathy for the railways in regard to restrictive legislation, if they themselves could agree whether they wanted these restrictions removed or wanted to impose them on their competitors.

The charge that in our joint rates with the railroads they are compelled to absorb 50 per cent of the saving by water is too ridiculous to answer. Our policy is, where there is a comparable route, all rail, to a comparable rail-water route, that the rail line performing its part of the rail-water haul, should get as its proportion of the accruing revenue, precisely what it should get from its connecting rail carrier for the same service.

Where there is no comparable route, we insist that each participating carrier shall get for its share of accruing revenue for joint service performed, a *fair* share, bearing some real relation to the cost of the service performed. The charge that the waterways are subsidized, and for that reason, are in unfair competition with the railroads, falls of its own weight. It is an endeavor to becloud the real issue.

Although the Federal Barge Lines have had a net operating income since the inception of the Inland Waterways Corporation; although no money has been appropriated for anything except expansions of the line; although the corporation could exist and operate and furnish cheap transportation indefinitely on its net operating income; although it has saved the public millions of dollars, charts such as the one published in connection with Prof. Ripleys article are constantly being presented to lead the public to believe that it is being mulcted. It is well to note that the Inland Waterways Corporation has existed only since the latter part of 1924, yet the greater part of these charges apply to the total expenditures on the waterways on which we operate.

"Certainly the people have been taxed to create and maintain our navigable streams, our harbors, our lighthouses, etc., to accomplish a

certain definite purpose, and since they have been taxed once to create them, why, in order to bolster up a case of 'hidden costs' should they be charged again with 'tax exemption,' 'maintenance of waterways,' 'interest and sinking fund on waterways,' 'interest on the corporation (their own) property'?"

The Inland Waterways Corporation is an agent owned by the people themselves, created by Congress to prove that, having taxed themselves to create navigable waterways, they can get that for which they have been taxed—cheaper transportation by water—something they had been unable to get for years, because water transportation has been destroyed by the railroads; and to saddle it in its pioneering demonstrative work, which is bringing back water transportation, with a preposterous system of charges which do not exist, which the people have willed should not exist, is to deny to the people the right to reap the benefit of the investment made.

But assuming that what our opponents claim should be charged against water transportation in the chart referred to are actually things which should be considered, let us point out the errors and discrepancies and let the reader judge whether they make a legitimate case.

This chart was evidently prepared from data contained in my annual report of 1928. Let us examine it.

It claims a "hidden cost" to the taxpayer of 0.7 mill per ton-mile on the ground of "tax exemption."

The total corporation "tax exemption," hidden cost as figured in this chart—0.7 mill per ton-mile for 1928—would amount to $1,066,741.90 or since the operating revenue for the year was $6,707,575.57, almost 16 per cent of the total revenue. According to statistics of railways in the United States, published by the Interstate Commerce Commission for 1928 taxes of class 1 steam railways were 6.37 per cent of the total operating revenues. Why charge the Inland Waterways Corporation almost 16 per cent tax exemption, or nearly three times as much as the railways are actually taxed? On the same basis that railroad taxes are calculated this "hidden cost" would be 0.26 mill per ton-mile.

But we have a better way of arriving at this than by comparison with railroad taxes; that is, by the actual taxes paid by common carriers by water in the United States. Out of 138 common carriers listed by the Interstate Commerce Commission on December 31, 1929, there were twenty companies which did not pay any taxes. The taxes paid by the remainder of the common water carriers amounted to only 1.55 per cent of the total operating revenues of these lines, instead of the 6.37 per cent paid by the railroads, and about 16 per cent charged against the Inland

Waterways Corporation to make a case of "hidden costs." On the same basis of taxation as other water carriers, the Inland Waterways Corporation would have paid 0.068 mill per ton-mile, instead of 0.7 mill per ton-mile, with which it is charged in the table for 1928.

On the basis of the original chart the "hidden cost" as given by the chart, of "maintenance of waterways," would be $2,773,528.94; "interest and sinking fund," $5,409,905.35; "interest on corporation property," $838,154.35—a total of $10,088,330.54—while the total freight revenue received by the corporation amounted to $6,445,353.70.

Why is this item "maintenance of waterways" charged to the Inland Waterways Corporation? According to a pamphlet issued by the Department of Commerce, there are 200 common carriers, 98 contract carriers and 187 private carriers, with a total value of $150,000,000, operating on the inland waterways of the United States. In 1928, to which year the table evidently referred, our value was approximately $16,000,000 or 10.66 per cent of the total invested on our inland waterways. Our proportionate share then (if such charge is legitimate) would be 0.19 mill per ton-mile for maintenance of waterways, instead, of 1.82 mills per ton mile. The interest and sinking fund on waterway (if such charge be legitimate) would be 0.378 mill per ton-mile.

Our "interest on the corporation property" evidently is here figured at 5.5 per cent of our actual value at the time. As a matter of fact the government can get all the money it wants at 4 per cent, so our interest would amount to only 0.4 mill per ton-mile.

Now add to the actual items the disclosed costs (which included a net income of $327,712.30) all that the table purports to give as hidden costs to get our final cost per ton-mile, and we have:

	Mills per ton mile
Tax exemption	* .26
Maintenance of waterway	.19
Interest on sinking fund	.38
Interest on corporation property	.40
Cost paid for transportation	4.23
Total	5.46

This total of 5.46 is opposed to 10.85 mills per ton-mile of the chart, and opposed to the actual operating costs of the railroads of almost exactly 10 mills per ton-mile, which do not disclose any "hidden costs" to the public of the donation of land grants to the railways since 1850, amounting to 132,173,224 acres, or of the $40,000,000 per annum subsidy through Pullman surcharges, or other items to be mentioned later.

* On the basis of taxation of other water carriers this would be reduced to .068.

It would undoubtedly surprise the public to know that this "land grant" by the government to the railroads is a continuing subsidy, since in the fiscal year 1930 there were 62,249.29 acres of land certified or patented on account of railroad grants by the United States to the railroads precisely as they were certified or patented (or granted) in the early days. One cannot be certain exactly what the 132,000,000 and more acres were sold for, but according to an advertisement issued by the Northern Pacific Railroad in 1871, the lands granted to the Union Pacific sold for $4.46 per acre; the school lands of the Illinois Central grant at $11 per acre, and the advertisement quotes an "average of $4 per acre."

The government price per acre at this time was given as $2.50 so that, taking this extremely low price, there is a "hidden cost" to the people of the United States of 132,000,000 acres at $2.50 per acre, or $330,000,000 given to the railroads to secure a "right of way," just as the money spent for rivers was given by the people to the people themselves to secure a "river right of way." The advertisement further states —"At only $2.50 per acre, government price, these lands (granted the Northern Pacific) will build and equip the road, leaving it free of debt, and place a surplus of twenty-five million dollars in the company's treasury."

Further, the rights of way thus given to the railroads by the government are carried in the value of the railroads, taken up as "investment in road and equipment," on which investment the people are requested to pay an additional five and three-fourths per cent return.

Not only were these land grants given by the government, but Texas, for example, donated many thousands of acres; counties and towns gave cash bonuses, or the proceeds of bond issues, for various purposes.

The people are entitled to the best form of transportation available at the cheapest possible rate, and if they desire to pay a part of the cost of transportation by highway, or by inland waterways, or by granting to the railways the present existing $40,000,000 subsidy of a surcharge on a Pullman ticket, they have a perfect right to do so. It would appear to be a much better policy on the part of all concerned not to attempt to mislead the people about hidden costs, but to furnish the best and cheapest possible transportation. Such transportation will come about through proper coordination and cooperation of all forms of transportation. It cannot be brought about by crying aloud that one form of transportation will destroy another, by bickerings, evasions of self-evident truths, or by unfair propaganda.

If one form of transportation is better and cheaper than any other, it will prevail, whether it destroys or partially destroys any other form or not.

There need be no fear of such contingency, however.

Personally, we believe that in giving the railroads the subsidies which have been mentioned, the people of the United States have done a wise and legitimate thing; we have no quarrel with the railroads—they are essential to our progress, and must be protected. It is only because they themselves have unfairly propagandized against so called "unfair and subsidized" competition, because they have attacked waterways, motorways, airways and pipe lines, that their attention is called to the fact that they, while living in a house of glass, have been caught throwing stones.

5. The charge that the railroads are being unjustly taxed to create a form of transportation calculated to hurt them has heretofore been answered by the Counsel for the Associated Industries of New York State in the following words:

"All property within the States is taxed, and the railroads are no exception to the general rule. The State not only has the right to tax property within its borders but it also has the right to spend the money so collected in the improvement of its highways, or for any other legitimate purpose. The suggestion that the State should not spend any tax money for the upkeep of the canal simply because some of the taxes are collected from the railroads is hardly to be taken seriously. By the same token the railroads might complain because some of the tax money is spent to build good roads. I might complain because some of my tax money goes to educate the children of my competitor. A street car company might complain because some tax money is spent to improve pavements over which taxicabs operate. Farmers might complain because some of their tax money is spent in the city. City dwellers might complain because some of their tax money is spent in aiding agriculture. And almost everybody might complain because Congress has directed that freight rates be made high enough to yield the railroads a fair return."

6. To the charge that thousands of railroad employees will be thrown out of business if the waterways increase in their success, I challenge any railroad in the United States to quote one single instance where a freight train has been removed from its schedule on account of purely water competition. Data collected by the St. Louis Chamber of Commerce, reading as follows, show quite the reverse:

"Referring to Annual Report of Rail and River Tonnage for 1926, * * * it shows that the increase in tonnage by all rail lines was 2.6 per cent and that the increase by the rail lines paralleling the Mississippi, increased 6 per cent. In other words, while there was an increase by all railroads of only 2.6 per cent, the lines in competition with the boat lines show an increase of 6 per cent."

Such charges grow and bloom from statements like the following, issued by the N. C. & St. L. Railroad to its employees:

"Five years ago the N. C. & St. L. Railroad had 9,684 employees, now it has 6,807. * * * Consider, for a moment, what will happen if the present situation is not corrected—more employees will lose their jobs. * * * The railroads have a right to urge that its competition in the public transportation business shall not be unduly favored in matters of regulation, public safety and taxation. It has a right to equal conditions of competition; it asks nothing more. * * * You should study this pamphlet and undertake to interest your family and friends, and above all, urge your representatives in the Legislature to favor such laws as will deal fairly with the situation."

A very careful study of this pamphlet reveals not the slightest criticism of our waterways, but of motor trucks and passenger vehicles. Nevertheless, extracted as I have extracted it, quoted in connection with attacks upon the waterways, the rank and file of the railway employees jump to the conclusion, or are deftly led to the conclusion, that the development of our waterways will hurt them by decreasing the number of trains. With cooperation, water development will increase the number of railroad employees.

A recent address by Mr. Rome C. Stephenson, President, American Bankers Association, who may be assumed to be an independent investigator, seems to me to confirm what has just been said. He hurls no charges against water transportation, although he does attack motor transportation and pipe lines.

The answer to the charge that the Inland Waterways Corporation should cease to exist, lies in the law itself, which prescribes when and how it may get out of business. A reasonable compliance with this law will certainly expedite getting the government out of business, and if you still feel that the operation of our Federal Barge Lines is a menace to rail prosperity, I call upon you to advise your railway executives to comply willingly and sympathetically with the law, and help us all attain quickly what we desire, the retirement of the government from the transportation business.

Demand from them that they comply with the spirit and intent of the law known as the Denison Act, to cooperate with the waterways to their own advantage, and not try to turn through technicalities, a law designed to increase and expand our water carriers and rail carriers through cooperation, into a weapon to destroy what the people have willed should exist, a great coordinated, cooperative, rail, water, motor, transport system.

ELECTRICITY IN THE ILLINOIS RIVER VALLEY

BY

EUGENE S. HIGHT

Assistant Vice President

North American Light and Power Company, Chicago

Since the earliest recorded history, the water courses of a nation have been the center of its greatest industrial and social development. In early times, this was due to the fact that these water courses afforded facilities for transportation permitting the interchange of goods as well as the intercourse of people. This condition lasted for many centuries and it was not until the railroads were generally extended over great sections of any country that the use of the water courses became less important. Even with the railroad development, the rivers have not entirely lost their first great usefulness to mankind.

In the last few years, however, a new condition has arisen as a result of which the water courses have again become important as centers of great industrial development with attendant increases in population. The primary reason for this change is the great quantity of water required for industrial operations.

The increase of population in growing industrial centers requires increasingly large supplies of food and for that reason industrial development is most rapid even under our present highly efficient rail transportation system, in the agricultural portions of the country where inexpensive fuel is available for the industries.

These conditions are present in the Illinois River Valley and have been generally recognized ever since Cavalier de LaSalle made his report to Louis XIII to the effect that this area had the potential possibilities of becoming an empire as great or greater than the Kingdom of France, with all and more of the advantages which his own country had, made available to the growth of civilization.

LaSalle, however, did not even dream of the powerful agent which was to be discovered in later years, and which was to have probably the greatest effect upon industrial and social development of all of the great discoveries which have been known to man—the discovery of electricity and the development of its possible uses.

I have been asked to discuss briefly this development in connection with the Illinois River Valley. In doing this, I have included the area

lying between Joliet and Alton and extending for perhaps 50 or 60 miles on either side of the main channel of Illinois River. This area contains approximately 10,000 square miles of which practically all the rural territory is rich farm land. Within this area are some 900,000 people, about half of whom live in prosperous and thriving communities and about half on the 42,000 farms throughout the agricultural portion. The many and varied industries require a total of approximately 375,000 horsepower for their operation. Horsepower used averages .42 per capita, which is indicative of the great industrial development that has taken place in this valley.

Power in some form has always been necessary for the development of any territory, and this is unusually true of the territory with which we are concerned. The need for this power was felt early in the history of the valley, and its development first took the form of water power. In 1830, a man by the name of John Green built a dam on the Fox River at Dayton, Illinois, and used the water power to operate a grist mill. In 1839, the State of Illinois built a new dam at this place for the primary purpose of delivering water to the Illinois and Michigan Canal at Ottawa.

To the owners of the mill at Dayton, however, was reserved one-quarter of the water supply, amounting to about 475 horsepower, and with this supply, which was much greater than that available from the old dam, the Green family operated the first woolen mill in Illinois. It continued in operation until 1882 when it was converted into a pressed brick plant, which in turn continued to operate until 1901. This was the first general industrial development of power in the Illinois River Valley, although a number of smaller grist mill operations had been conducted on the subsidiary streams during this time.

In February of 1881, the Joliet Electric Light & Power Company was incorporated for the purpose of building a steam plant for the production of electricity. This date is earlier than that of the incorporation of the company that built the Pearl Street Station in New York City, which was the first one put into operation in United States for the commercial production of electricity. However, the Pearl Street Station went into operation in 1882 and the Joliet Station did not begin to deliver electricity until 1883. In the year 1899 a power station was operated at Ottawa, Illinois, for the purpose of supplying energy to an electric street railway company. This was the first electrically operated railway in the State.

Initially in the electricity industry, energy was generated as direct current and could be distributed only short distances from the center of generation. With the development of alternating current and the im-

provement of insulation material, which permitted higher voltage generation, the area that could be supplied from the central station was greatly increased. Greater numbers of people learned of the advantages that could be obtained by the use of electricity and demanded service so that the engineers of the industry were required to develop rapidly methods of distributing this energy greater distances. This led to the transmission line. In 1893 a single phase line with a voltage of 1,100 was built from Elmwood to Yates City, and in 1901, a 33,000 volt line, with a type of construction very similar to that now in use, was built from Joliet north to Blue Island. These were apparently the first transmission lines in operation in this great river valley.

The development of the steam turbine probably had the greatest single effect upon the development of the electricity industry for the reason that it permitted the production of electrical energy with constantly decreasing quantities of fuel. The first turbines which were installed early in this century required from 4 to 5 pounds of Illinois coal to produce one kilowatt hour. At the present time turbines are producing as much energy with slightly more than one pound of such coal. The first turbines had capacities ranging from 1,000 to 5,000 kilowatts; at present turbines on single shafts as large as 160,000 kilowatts are in operation.

This development, resulting from the increased necessity of reducing the costs of generating energy and the ability to control high voltage have resulted in the concentration of energy production in large central power stations from which the energy is distributed over large areas. However, the production of this energy from large central stations requires enormous quantities of water, with the result that such large centers of production must be located where large quantities of water are available and if possible, near sources of reasonably inexpensive fuel supplies. For example, the city of Peoria requires approximately 8,750,000 gallons of water per day for its normal operations. The plant across the river from Peoria which supplies this area with electrical energy uses approximately 55,000,000 gallons per day or more than six time as much as the whole city of Peoria.

A typical example of a modern central production plant is that at Powerton near Pekin on Illinois River. This station has a present capacity of approximately 225,000 kilowatts and another unit of 110,000 kilowatts will shortly be installed. It has a proposed ultimate capacity of more than 500,000 kilowatts and requires at the present time the enormous quantity of 240,000,000 gallons of water per day for its operation. It is the most efficient power station in the world, so far as records can

be obtained, and it is without question the most efficient power station in the United States.

The Powerton plant is one of the sources of electrical energy supply for the Illinois River Valley area. The plant across the river from Peoria with its capacity of approximately 60,000 kilowatts is another major source of such supply. A number of smaller plants are located in the Illinois River Valley area, and the total available capacity of such stations for this territory is approximately 535,000 kilowatts.

By means of the transmission line network which extends through the valley, these stations are interconnected with the enormous pool of power in the Chicago area which has a capacity of almost 1,500,000 kilowatts. They are also connected with the great St. Louis pool, which is interconnected with the hydro-electric plant at Keokuk and will shortly be connected with the new great hydro-electric development at Bagnell, Missouri, when it will have a total available capacity of 550,000 kilowatts.

Energy is distributed in this area largely by 66,000 and 33,000 volt transmission lines. The main trunk line which follows generally the Illinois River Valley from Pekin to Chicago operates at 132,000 volts. There are more than 6,600 miles of transmission and distribution lines in this area which deliver energy to 200,000 consumers.

The construction of these large central stations, high voltage lines and distribution networks is enormously expensive, as evidenced by the tremendous increases in capital investment which are necessary from year to year to provide equipment to meet the growing demands of the people for electric service. More than ten billion dollars worth of this equipment is now in use in this country and nearly one billion dollars are expended annually in order to keep pace with the growing demands.

Of necessity the new developments which require these enormous sums of money must be made with a capacity far in excess of the present requirements. It would be extremely improvident to build for today without giving careful consideration to the demands of tomorrow. This fact presents a very serious problem to the management of the electricity supply companies, that of making rates for the sale of electric service so low that the greatest possible number of people and industries may have the advantages which electric service brings, yet of maintaining the rates sufficiently high that a reasonable return may be earned on the initial investments which have been made to provide for future demands. The gentlemen among you who are connected with the operation of manufacturing plants know the effect of mass production on the cost of making and distributing a product. It is upon the effect of mass production and distribution that the electricity supply industry is de-

pending to make these expenditures for the future successful from a financial standpoint. The manufacturing industry which is producing electricity for its own use does not usually consider the fixed charges on the investment in its power station as a part of its total cost of power. A great many times this investment has already been written off out of the profits of the industry. This is not true of the electricity supply business and at times it becomes very difficult to supply electrical energy from a super-power network, at a rate which must include the fixed charges on the investment, to an industry which considers as the total cost of its own electricity only the operating charges necessary to manufacture it. However, the fact is patent that as these industries grow they will require additional power facilities when the fixed charges will become an obvious element of the power cost. As the electricity supply from a super-power system grows, the amount of investment which must be charged per unit of electric service becomes continually smaller, and therefore, the power supply company will continually improve its position in respect to being able to deliver quantities of energy to manufacturing plants at costs attractive to manufacturers. Of this gradual change in the economic relation of power supply to the industries, I invite the serious consideration of those gentlemen who are responsible for the lowest possible costs of their manufactured product.

Of the total power requirements of the industries in this Illinois Valley area, amounting to 375,000 horsepower, 300,000 horsepower is operated electrically and of this latter figure, approximately 250,000 horsepower is supplied from this distribution network. This indicates the extent to which the business men in charge of these industries realize the advantages of the uses of electrical energy.

However, these uses are not confined to the urban population and to these industries. There are approximately 42,000 farms in this area. Ten years ago, only a very few of these farms were supplied with electricity, but at present time more than 5,350 of them or 12.7 per cent of the total number, are supplied. This percentage compares very favorably with that of the entire State of Illinois, which is 9.8 per cent of the total number of farms in the State. Farm homes are demanding electrical service and rapid progress is being made in connecting them.

It is an aspiration of the men who have given their lives to the development of an adequate and economical supply of electricity, that within a reasonable time there shall not be one single home, business establishment, or industry which shall not have at an economical cost the advantages that electric service from a super-power system can bring. This conception is almost unbelievable in its far reaching possibilities. We do not realize that although there are more than two

hundred thousand users of electricity in the Illinois Valley, yet even at the present cost of electric service which is generally lower than it has ever been in this history of the industry, in 65 per cent of the homes in this area the old dust raising broom is still used for sweeping floors; in 75 per cent of the homes the old-fashioned washboard and wringer are still in use; in 96 per cent of the homes in towns that have no gas supply the old fashioned range is still operated when the same wire that brings the light to the home could also furnish a fuel available at the turn of a switch which would cook more efficiently than either coal or wood.

That is generally the case, but suppose we look at the rural communities. Only 13 per cent of the homes have electric service and in only 9 per cent of these homes is electricity used to sweep the floors or help in the other household work. Less than 7 per cent use electricity for pumping water into the house. In only 4 per cent of the farm homes is there an electric cooking range. The power separator is used in less than 3 per cent of all the farms and in only 2 per cent are there electrically driven sewing machines.

In the industries, however, the use of electricity is further advanced. Based on the report of The Power Survey Committee for the Great Lakes Division of the National Electric Light Association it has been determined that in 1920 there were approximately 180,000 horsepower of electric motors in the Illinois River Valley connected to super-power service. Based upon the rates of growth over the past twenty years, by 1940 or nine years from now, there should be a total horsepower installed in the industries of the Illinois River Valley of nearly one million. If by that time only one-half of this large amount of motive power were supplied by the super-power networks, this would still be approximately twice the present amount of motive power supplied and would represent an increase of more than 250,000 kilowatts for these industries alone.

In addition to these uses there will be special developments in the use of electricity, for the electrification of railroads, the development of the wireless communication systems and for the operation of devices which are even now only in the process of being discovered.

There is a new civilization being developed here in this great country of ours. A civilization, not built as those old civilizations were, on the slavery of human muscles but founded upon the development of natural resources and upon the power and energy of ions and molecules controlled through the knowledge obtained from the advancement of the physical sciences; a far more stable and enduring foundation

than that above which the civilization of Greece and Rome towered and finally fell when their foundations of human slavery crumbled.

President Hoover is quoted as saying "As we furnish power at less and less cost and as we increase the volume of its supply, we decrease the sweat of men and the drudgery of women." So we may look forward to a time not so distant in the future when by means of these great super-power networks, if they are permitted to develop unhampered by the narrow prejudices of short-sighted political leaders and may have the continued intelligent supervision of State regulating bodies, the whole Illinois Valley will be so completely, adequately, and economically supplied with electric service that the physical toil in the home and in the industries will be practically removed and this great social and industrial development of ours, so far ahead of that of any other country in the world, will reach a point almost unimaginable in the growth of industry, and in the comforts of living.

LAND UTILIZATION IN THE ILLINOIS RIVER BASIN

BY

CHARLES L. STEWART

University of Illinois, Urbana

The Illinois River system serves as an outlet for an entire area of 26 Illinois counties containing nearly nine million (8,747,520) acres, and for parts of 27 additional counties. In those 27 counties more than 6½ million (6,695,680) acres are estimated to be drained by Illinois River and its tributaries. The 15½ million acres in the 53 counties of Illinois which send their water to Illinois River constitute all but 14 per cent of the total area drained by this river and its tributaries. Nine counties in Indiana and four in Wisconsin also contribute, the former through the Kankakee and Iroquois, the latter through the Fox and Des Plaines rivers. The total area drained through the Illinois River system is equal to 50 per cent of the 35,867,520 acres of land in Illinois. Illinois River drains 43 per cent of the State and the area in all counties drained entirely by the Illinois River system is 25 per cent of the State.

Nine main tributaries empty directly into Illinois River. These are the Kankakee, Des Plaines, Fox, Vermilion, Mackinaw, Sangamon, and Spoon rivers and Crooked and Macoupin creeks each of which drains more than a half million acres. Two of them, in their turn, have large tributaries—the Kankakee has the Iroquois River, and the Sangamon has its South Fork and Salt Creek. Counting these tributaries the Kankakee and Sangamon each drain more than 3¼ million acres.

In addition to the nine main streams feeding directly into the Illinois there are many small ones. The amount of land served by this immediate drainage is 7,055 square miles, which is nearly one-third of the Illinois area served by the river.

With this background, we may turn toward some of the questions of land utilization in the watershed of Illinois River with its outreach into the heart of one of the nation's most important agricultural regions. According to computations based on the 1930 census figures which have become available for the first time within the past ten days, the 26 counties dependent entirely upon Illinois River drainage had 95.4 per cent of their land area in farms. It would be difficult to find a more complete utilization of land in agriculture than in some of these counties.

Using as our basis all land in farms, it appears that 73.5 per cent of it was crop land in 1929, 22.2 per cent pasture land, 1.1 per cent woodland not pasture, and 3.2 per cent all other farm land. Taking the 6 million (6,155,190) acres of crop land by itself, 94.3 per cent was harvested in 1929, 2.8 per cent had crop failure, and 2.9 per cent was idle. For so large an area as a whole, less idle or failure land could hardly be expected in that year of considerable overflow.

The 1929 ratios of crop land which were classified as failure and idle land were larger in the lowland counties. Counties in which more than 5 per cent of the crop land was classified as having crop failure that year were as follows: Cass, 8.1; Logan, 7.5; Schuyler, 6.9; Mason, 6.3; Fulton, 5.4; and Menard, 5.0 per cent. Idle crop land was similarly prominent in Green, 10.6; Scott, 8.3; Cass, 7.2; Schuyler, 6.5; Brown, 5.8; and McDonough, 5.5 per cent. When both types are added together, Cass with 15.3; Greene, 14.6; Schuyler, 13.4; and Scott, 11.9 per cent take the lead.

Taking the nearly two million (1,843,761) acres of pasture land by itself, 45.5 per cent was plowable, 33.7 per cent was woodland, and 20.8 per cent was neither woodland nor plowable. Of the 7½ million (7,524,726) acres of pasture in Illinois as a whole, 55.5 per cent was plowable, 26.5 per cent was woodland, and 18.0 per cent was other pasture land. Woodland occupied a larger relative place in the 26 counties than in the rest of the state, this being due in considerable measure to the fact that land broken by streams normally carries a larger proportion of woodland.

For the period 1925 to 1930, the trends in land use in the 26 counties may be summarized as follows:

Area of all land in farms increased 2.0 per cent in the basin and decreased 0.1 per cent in the state as a whole.

Harvested crop land decreased 0.2 per cent in the basin and 4.4 per cent in the state.

Crop failure land increased in both basin and state, 6.0 and 13.0 per cent, respectively.

The same was true of idle land, but increases were much more marked, being more than 340 per cent in the basin and nearly 70 per cent in the state.

Woods pasture was increased 3.0 and 5.0 per cent, respectively, in both basin and state; plowable pasture increased in the basin 3.5 per cent but decreased 0.2 per cent in the state; other pasture increased 7.0 per cent in the basin and 10 per cent in the state. The fact that this permanent pasture on non-tillable land increased in the basin more markedly than did both plowable and woodland pasture, and that all

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pasture increased 4 per cent in those counties is all the more significant when viewed in the light of reduced acreage of land in harvested crops. It is only as the increased area of crop failure and idle crop land is included that it is possible to say that the area of crop land was increased in the basin.

This comparative stability in the utilization of the land in the parts of Illinois referred to may be somewhat surprising in the light of the subsidence of land valuations. In 1930 the estimated value of the average acre of farm land, excluding buildings, in the 26 counties was less than that of 1920 by 46 per cent. In the state as a whole the decline was nearly 50 per cent. Almost exactly half of it occurred between 1925 and 1930.

This decline was not confined to any part of the basin territory. Only one county, DuPage, failed to show a decrease. Counties of lowest valuations in 1920, such as Brown, Greene, Schuyler, Mason, Scott, Cass, and Fulton, had rates of decrease somewhat smaller than counties having high valuations in 1920. The decreases in counties such as McLean, Livingston, DeWitt, Woodford, Logan, and LaSalle, ranged from $145 to $182 per acre. Decreases in lowland counties were about $100 less per acre. This was probably a result of a tendency for the upland counties to be vastly overvalued in 1920, a condition which applied to limited portions of the lowland counties, also. The land especially suited to corn and wheat, whether in the reclaimed areas or in the uplands, was outstandingly overvalued in 1920. Township figures on Illinois farm land valuations have been published for 1920 for only the counties near Chicago, but figures for 1930 will shortly be available for the entire state. Although no such comparisons with 1920 figures will probably be available for most of the 26 counties included here, there is little doubt that shrinkages in valuation in drainage townships have in many cases been very severe.

The valuation of buildings on the farms of the 26 counties, as in the state as a whole, held their own from 1920 to 1930. In 1930, for the first time we are able to know the valuation of farm dwellings apart from the barns and other buildings. Farm dwellings averaged $2,185.50 per farm in the 26 counties, an amount larger by $391.30, or 18 per cent, than in the state as a whole. In general, the other buildings had a valuation as large or slightly larger than that of the dwellings.

It has been suggested that the valuation of farm real estate had much to do with the proportion of farm land that found its way into tenant operation. Farm tenants were found operating a larger proportion of the farms where acre valuations were high and this is the present situation to a considerable degree. The percentage of farms oper-

ated by tenants in the 26 counties in 1930 ranged from 36 in Brown to 67 in Grundy. In 14 of the counties more than 50 per cent of the farms were tenant operated. In four of them, Grundy, Logan, Livingston and McLean, the percentage exceeded 60. Outside of the United Kingdom there is probably no other equally large area in which, in the absence of differences in race or cast, such large proportions of the farm real estate are in tenant hands. It is precisely in the counties of most valuable real estate that tenant operations have reached largest prominence.

The decline in land valuations has not brought a decline in prominence of tenancy. In fact, decline in proportion of farms rented, from 1920 to 1930, was found only in Fulton, Mason, Peoria, Morgan, and Livingston counties. The largest change was less than 2 percentage points in any of these five counties. The 21 counties showing increase in tenancy also showed relatively small changes in most instances.

Information as to land mortgage indebtedness on farms is not yet available from the 1930 census, but it is probable that a larger proportion of owner farmers have mortgages and that the ratio of mortgage debt to real estate valuation is higher than at previous census dates.

Land tax delinquency for 1929 has been ascertained in 10 of the 26 counties. The amount of taxes on land sold in 1930 for 1929 general taxes ranged from $1,484.58 in Menard County to $42,428.19 in Schuyler, the total being $104,851. This was 81 per cent more than the corresponding figures of three years before.

The land in drainage enterprises comes in for special attention in any study of land utilization in watersheds. The 1930 census includes information for 22 of the 26 counties in a form comparable to that collected in 1920. The acreage reported in 1930 was 994,327, an increase of nearly 30 per cent over the 771,312 acres reported in 1920. This is a rate of increase slightly in excess of that shown for the state as a whole. It indicates little in the opinion of the writer, inasmuch as the more accurate survey of 1928 made by Professor G. W. Pickels and associates at the University of Illinois, showed 10 per cent more land in active drainage enterprises than even the 1930 census shows.

The fact that only one-fifth of the drainage district land of the state is in the 26 counties may seem strange. One of the counties which drains partly into the Sangamon, namely Champaign county, has nearly half as much acreage in drainage districts as the entire 26 counties.

In the case of the land served by both drainage ditches and dikes, or levees, the situation is more critical. Testifying before the Committee on Irrigation and Reclamation, U. S. House of Representatives, in April, 1930, there were few officials of state associations of drainage

and levee districts who painted a more dismal picture than did President J. P. Kerr, of Illinois. He pointed out that:

"In the first place agriculture has not been a paying business. This has been especially burdensome on drainage district farms. * * * Since 1920 until the present year, there have been storms and floods, wet seasons on such a scale and to such an extent never before equalled in the history of the state. * * * These flood conditions, as they have continued year after year during the last decade, have greatly weakened, and in many cases destroyed, original levee works, and have caused a vast acreage of land inside levee districts to be unproductive because of water-soaked soils.

"In years past drainage bonds sold at a premium and promptly. Today such bonds will not sell at all, or only in very rare cases, where they will sell at a high rate of interest."

The distinction between upland drainage districts and lowland drainage districts becomes important at this point.

The capital invested in drainage enterprises, as reported by the census of 1920 was $43,595,069. In 1930 the aggregate is given as $74,333,065. The average per acre was about $11 in 1920 and nearly $15 in 1930. In upland counties such as Champaign or Ford the capital invested per acre has been below these averages. In some of the lowland counties, however, the amounts run several times as high. In Peoria county, for example, 6,446 acres in drainage enterprises were credited with a capital investment of $484,935. Where the reclamation outlay has been so large, it is only in the rarest instances that carrying charges have been easily met.

Data supplied in tabular form to Congressional committees last year may be summarized as follows for the 15 drainage and land districts included along Illinois River from Hennepin to Grafton:

Number of land owners	1,164
Acres in districts	99,319
Acres in cultivation	94,936
Acres cleared, not cultivated in 1930	1,775
Assessed valuation	$3,872,174.00
State and county taxes, 1930	$82,793.80
Drainage taxes, 1930	$331,340.24
All other taxes, 1930	$35,000.00
Acres delinquent, 1930	5,529
Drainage bonds outstanding	$2,437,164.87

Of the land in the Illinois Valley levee and drainage districts included here, 95 per cent was in cultivation. In 20 other districts for which information was given in the House hearings, only about 20 per cent was in cultivation. Even so $4.50 an acre taxes on land producing staple farm products has been an enormous load in periods of low prices and high costs.

It is evident that these lowland drainage districts represent for the most part investments which reflect agricultural hopes of the period before 1920 rather than realizations of the period since. A post-war land utilization reversal has struck many of these enterprises a staggering blow.

Suggestions that a cleaned river will mean the reappearance of new uses for the flood plain areas are all about us. Will restored lakes in some cases afford the quiet waters needed by young fish when inland fisheries again become prominent on Illinois River? Will recreational uses, private, commercial, and public, take in some of this area to the relief of the drainage farmers? Will a rewriting of the bonded indebtedness on a basis of slower amortization and a tempered interest rate help to stabilize the situation for existing owners and operators of drainage land?

Whatever the answers to these questions may be, five points seem to the writer to be worth the serious attention of our students of theoretical and applied economics.

(1) The river drainage basin as a differential area in land utilization studies, although less significant in the heart of the corn belt than in many other regions, may, nevertheless, be recognized as having an economic as well as legal unity, the importance of which is to be noted especially when the dominant upland portions of the basin throw their run-off upon the servient lowland portions with exceptionally widespread damage in flood-plains of the river itself and of its principal tributaries.

(2) The economic relation of dominant to servient areas presents more acute problems in the valleys of the Mississippi and its tributaries, most of them notably muddy rivers, than in the valleys of the clear rivers of England, with respect to which the common law conceptions which we inherited were developed. With our more spasmodic climate, with flat areas provided with tile and ditch drainage, and with the removal of forest and other cover which might delay the run-off of rain and melted snow, the servient areas are called upon to aid the dominant areas in a degree beyond that of earlier years. This relationship holds to some extent in the more outlying watersheds and to an especially marked degree in the downstream areas. It is difficult to base State and Federal participation in the cost of river control upon a formula expressing indisputable equities, but a considerable degree of such participation is ordinarily justified.

(3) Shifts in prices, without corresponding changes in drainage, levee, and general property taxes and in interest charges have placed former overflow land at a comparative disadvantage, so that in utiliza-

tion they can not compete equally with lands having better natural drainage.

(4) Districts overwhelmed by delinquencies might in some cases be taken over advantageously for purposes of general river conservation.

(5) A comprehensive study of the situation in the original flood-plain of the Illinois and some of the tributaries to the end that an adequate public policy may be formulated is plainly needed. Data concerning land utilization, land valuations, and some other subjects will shortly be available not merely on the county basis, which only crudely fits the need of the problem, but also on the basis of townships. With 1930 census results analyzed for the 1860 or more minor civil divisions of the state—without expense so far as many of the more important lines of information are concerned—and with additional information as to soils, drainage, and other problems already assembled in the Agricultural and Engineering Experiment Stations, in the State Geological, Natural History, and Water Surveys, the State Departments of Agriculture and Conservation, and elsewhere in the various state institutions and administrative agencies, the informational basis for a replanned use of the troubled lands and water should be laid readily and well. The return of a clean river, with increased flow of water at least in all but flood periods, may open the way for a utilization less wasteful, less competitive with agriculture in the uplands, and better adjusted to the needs of the state.

SOME PROBLEMS IN FLOOD CONTROL

BY
JACOB A. HARMAN
Consulting Engineer, Peoria, Illinois

INTRODUCTION

Flood problems are as old as civilization. History, tradition, and the remains of prehistoric structures disclose the work of man for flood control. Natural stream channels are developed and continuously modified by erosion and deposition of soil materials. Steep slopes produce velocities of greater eroding and transporting power. Soil materials are disintegrated and reduced to smaller particles by the rubbing and grinding incident to the movement by flowing water. In alluvial valleys, stream channels develop bank-full capacities approximately equal to the average annual flood discharges. Maximum floods exceed the average annual flood by two to ten fold. The channels of streams which have frequent floods and greater annual flows are more stable, other things being equal, than those which have lower annual flows and occasional great floods.

WATER

Water, the universal solvent, occupies a most prominent place in the scheme of nature and in the life and attainments of man. It is found and used as vapor, liquid, and solid and is combined with other elements into innumerable substances in nature or produced in the kitchen, laboratory, or factory.

Water occupies three-fourths of the earth's surface. Water vapor, evolved from the water surfaces, is carried by warm air currents and is precipitated as rain or snow when condensed by mingling with colder air currents.

PRECIPITATION

The distribution of precipitation (rain and snow) on land and sea follows nature's laws, but due to varying conditions of climate, including effects of temperature, air currents, and the topography of the land, precipitation ranges from practically nothing on so-called arid areas to a maximum depth of 25 feet or more annually. The annual range of precipitation in this locality—Peoria, Illinois—is from about 20 inches to more than 60 inches.

The time and amount of precipitation are not within the control of man but by study of the accumulated meteorological records many of the laws, conditions, and forces influencing precipitation have been identified and satisfactorily accounted for, so the time, location, and amount of precipitation may be predicted with some degree of assurance. However, the future occurrence of excessive precipitation can only be anticipated by applying mathematical theory of probabilities based on recorded experiences. The records frequently are too few and their accuracy only approximate. The first problem in flood protection or prevention is *precipitation, its duration, amount, intensity and local distribution and the prevailing temperatures.*

Relation of Rainfall to Run-off

Destructive floods on small streams are produced by excessive rainfall, frequently referred to as cloudbursts, and on larger streams by prolonged rainfall of unusual intensities over large areas. In the temperate zones, snow is frequently melted by warm rains and adds to the spring freshets. In the Mississippi Valley, spring and summer rains follow in cycles of about one week and the great floods follow unusually heavy storms when the ground is frozen or saturated and the channels full from previous rains. Our second problem is therefore the *relation of rainfall to run-off.*

Published Data

Rainfall and stream flow data have been collected and published by the U. S. Weather Bureau and the U. S. Geological Survey for many years. This work is supported by the states and supplemented by cities and other public and private interests. These data as they apply to each stream are used in flood control studies. Estimates of probable flood discharges and frequency are based largely upon the daily flow of the stream, if it has an acceptable record for ten years or more, using mathematical probability curves found to most nearly follow the flood experiences with similar areas having longer records. In some eastern states flood-flow records are available for more than one hundred years. In Europe some records cover three hundred to five hundred years.

For streams with few or no flow records, flood flows are estimated by analogy from data of other watersheds. Rainfall records cover much longer periods than stream flow data. The relation of rainfall to run-off where both are known furnishes a basis for the extension of flood predictions and their application to similar watersheds similarily situated.

Geological and Topographic Formations

The geological formation and topography of a watershed, and the prevailing temperatures are next in importance to rainfall in determ-

ining flood flows. Open, sandy, level land will store much water which flows underground and does not contribute to floods. Frozen, heavy, or rocky land will absorb little and the major portion of all rain produces flood flow. Lakes and reservoirs and overflowed valley lands store or detain surface flow. The third problem in flood control studies may readily be the *storage capacities underground, in lakes and reservoirs, and on low level lands,* and their bearing upon the relation of rainfall to run-off.

Erosion and Transportation of Soil Materials

Soil materials, clay, silt, sands and gravel, are eroded from the hillsides, transported by flowing water to the valleys and deposited where the velocities are retarded. These eroded materials are carried along by the streams and deposited in the valleys, thus forming plains or deltas of alluvial soils which are the most fertile agricultural lands. Cultivation exposes the surface to erosion. In rolling and hilly areas terracing is applied to prevent erosion. This method of cultivation also detains the rain on the ground longer than farming on natural slopes and reduces floods from such areas. Erosive velocities are to be avoided as far as practicable in channel improvements for flood relief.

The fourth problem therefore in flood control may refer to the consideration of *methods for prevention of erosion and transportation of soil by surface waters and streams.*

Diversion From Lake Michigan

During the past thirty years an average of about 8,000 cubic feet per second of water has been flowing from Lake Michigan through Chicago River and Chicago Sanitary and Ship Canal into Des Plaines River at Lockport, thence through Illinois and Mississippi rivers to the Gulf. This flow has been practically continuous and frequently when Illinois River and its tributaries are in flood, the flow from the sanitary canal at Lockport has been more than the average. This diversion from Lake Michigan into Illinois River has increased the flood hazard and increases the cost of flood protection works.

The stages of Illinois River have been increased by diversion from Lake Michigan through the Chicago Sanitary and Ship Canal about 5½ feet at low water and about 1½ feet at high water on the Peoria gauge. The high water stages of the Illinois are increased by diversion from Lake Michigan about 1 foot on the Beardstown gauge since the levees were built and from 5/10 to 6/10 of a foot before the levees were built.

Illinois Floods in Relation to Navigation

Illinois River is being improved by the Federal government for a 9-foot navigable depth at low water with an 8-foot gauge height in Peoria. Five dams with navigation locks are located in the upper Illinois and Des Plaines rivers as follows: at Starved Rock above LaSalle; at Marseilles; at Dresden Island, below the junction of the Kankakee and Des Plaines rivers which form the Illinois at Brandon Bridge, below Joliet; and at Lockport, the west end of Chicago Sanitary and Ship Canal. This plan was based upon a flow from Chicago Sanitary and Ship Canal of about 6,500 cubic feet per second through the controlling works at Lockport during low water in Illinois River. It may be necessary to continue to maintain dams and locks in the lower Illinois River to sustain a navigable depth of 9 feet if the diversion is reduced to 1,500 cubic feet per second, as indicated by the decision of the Supreme Court a few months ago. Four dams have been maintained in Illinois River for a navigable depth of 6 or 7 feet and experience has shown that these dams have had no material effect on flood stages. The dams in Illinois River between Lockport and Starved Rock are designed with gates so that the flood stages are not to be increased. The construction and maintenance of dams for navigation in Illinois River therefore are not considered to present any new flood-control problems.

Flood Prevention Agencies

Flood prevention in its early stages was by individual initiative. A landowner, to protect some cultivated area from overflow, constructed small levees. This was followed by other owners acting individually or by mutual agreement and subsequently by organizing taxing districts for constructing and maintaining such work. In the Illinois Valley a number of small private levees were built by individual owners before the State Legislature enacted laws for the organization of levee districts with taxing powers. All levees along Illinois River are now under the levee laws of the State. Other states in the Mississippi Valley have enacted similar laws.

Along Mississippi River and some of the larger tributaries the flood areas extend into two or more states. Portions of 31 states, 40 per cent of the entire area of the United States, drain through Mississippi River, and the Mississippi flood problem has been recognized as national in scope since the United States came into possession of both banks of the river. Numerous reports have been made under authority of Congress, from 1850 to the present time. The Chief of Engineers of the United States Army has recently made a report to the Secretary of War with recommendations for the completion of the flood control work

on Mississippi River from Cape Girardeau to the Gulf substantially as authorized by an Act of Congress in 1928 following the disastrous flood of 1927.

The Illinois Legislature, since the flood of 1926-1927, in recognition of the public interest and the public benefit resulting from the protection of the property of its citizens, has appropriated more than $3,000,000 for flood relief and flood protection, a large portion of which applied to the Illinois Valley.

The agencies of flood control are therefore (1) the owners of the land, acting individually or collectively, (2) the district or municipality, (3) the State, and (4) the Federal Government, each contributing its proportionate share as the benefits may appear.

Engineering Methods of Flood Relief

Three general methods are employed for flood relief works, namely,

1. **Channel improvement giving greater carrying capacity.**
2. **Levees for protection from overflow with resulting increased flood heights.**
3. **Storage in holding reservoirs or in detention basins.**

The first two methods, channel improvement and levees, are the most commonly used, but each method produces new problems and frequently may produce new flood hazards. Alluvial valley stream channels are unstable. In streams of steep valleys the bed and banks are being eroded continuously. Some portions of the bank are removed and deposited in an eddy forming bars at down-stream points. In this way the streams tends to lengthen and establish itself on a flatter gradient with a more stable channel. When bends are cut, the velocity is greater, erosion is increased and channel protection is required to maintain a stable channel. The usual effect of stream straightening in this locality is for the channel to widen by erosion and become filled by the coarser sand and gravel so that in a few years it is necessary to re-excavate a portion of the channel to have the water-table in the adjacent valley low enough for agricultural drainage.

Levees remove overflowed land from the floodway, increasing flood heights, first, by reducing the storage area available and making it necessary for the floods to pass through the valley in less time and at greater rate of flow; and second, by reducing the flood cross-section of the stream thus causing the river to rise higher between the levees to overcome both of these restrictions.

Storage, in order to be effective in reducing floods, must be empty when the floods come. On the other hand, conservation of flood waters

for municipal and power purposes, for irrigation or for maintaining navigation through the low water periods requires that the storage reservoirs be maintained full because the time and amount of precipitation can not be predetermined. Therefore, flood control through detention and storage reservoirs that are to function for conservation of the water, must be a compromise.

The engineering methods that are to be employed therefore depend upon the economic conditions and will change as population and industrial enterprises in the Illinois Valley increase. It is reasonable to anticipate that within the next two or three decades the industrial development in the Illinois Valley will call for the conservation of the flood waters and will result in helping to solve some of the flood control problems in connection with our water supply developments.

Detention and Storage Reservoirs

Flood prevention by storage has been applied successfully on many streams in Europe. The most striking example in America is the flood detention reservoirs of the Miami Conservancy District in Ohio where the flood water is detained behind dams with outlets restricted to a capacity which the channel below will carry without damage to the adjacent valley lands and property.

Many storage reservoirs have been constructed for municipal and sanitary water supplies, for power development, and for irrigation. The cities located upon the Great Lakes, Chicago, Detroit, Cleveland, Buffalo, etc., obtain their water supplies from the lakes upon which they are located; New York City from storage reservoirs located in the mountainous areas north of the city; Philadelphia by pumping from the Delaware River and filtration; Boston from storage reservoirs on the Merrimac and other streams of the State; St. Louis, New Orleans and many of the other Mississippi River cities by pumping from the river and by filtering; western cities on both sides of the Rocky Mountains by storage reservoirs. Los Angeles now takes its principal supply from a mountain stream 275 miles from the city and will take an additional supply from the new Hoover Dam on the Colorado River more than 300 miles from the city.

Irrigation and Flood Control

Irrigation of the arid and semi-arid lands of the western portion of the United States is made possible by storing the flood waters and feeding it out as needed. All of these storage projects influence the flood stages of the streams upon which they are located.

It does not seem probable that storage of water for irrigation will be a factor in flood control in the Illinois Valley.

Flood Prevention in the Illinois River

Storage Effects

Consideration has been given to the prevention of floods by storage, but to appreciably reduce flood stages in the Illinois Valley, much valuable agricultural land would be taken for flood control reservoirs. Levees for flood protection have therefore received the approval of State authorities and landowners.

The extent of storage areas required in the Illinois Valley may be illustrated by considering the natural storage in one of the major floods between Peoria and LaSalle. The length of the valley from Peoria to LaSalle is about 60 miles and the average width at flood stage is about 1½ miles, an area of about 57,000 acres. The river had been at about a 19-foot stage for more than two weeks and rose 5.45 feet to 24.65-foot stage at Peoria from April 16th to April 24, 1927. On May 15th the flood had receded to a 19-foot stage. During that thirty-day period, 2,500,000 acre-feet of water flowed past Peoria. During the 9 days of rising stage, from April 16th to 24th, the total discharge at Peoria was 778,000 acre-feet and the added storage was 315,000 acre-feet, or a total flood-water inflow of 1,092,000 acre-feet. The added storage was about 28.8 per cent of the total inflow or 40½ per cent of the total outflow for the rising period. At the beginning of this rise on April 15th there was an average depth of overflow in this portion of the Illinois Valley of about 7 feet, and storage of about 500,000 acre-feet making 800,000 acre-feet stored at the crest of the flood. When we consider that the amount of water storage in the Illinois River Valley at this flood period was sufficient to cover 800,000 acres, or an area 60 miles long and 21 miles wide one foot deep, we may visualize the magnitude of the problem of providing storage area sufficient to materially modify flood stages. It is also necessary to have in mind that storage, to be available for reducing flood stages, must be empty when the flood waters come, otherwise it would be of no value. The conservation of water for municipal and industrial purposes in storage reservoirs is useful for flood relief only before the storage capacity is filled. The records show that the great floods have always been produced by heavy rainfall after the underground storage and the lakes, ponds, reservoirs and overflowed areas have been substantially filled.

Levees for Protection of Illinois Valley Lands

The Illinois River Valley from Starved Rock to the Mississippi, a distance of about 230 miles, is from one mile to six miles wide, and averages more than two and one-half miles in width. The total overflowed area, including river channel, is about 400,000 acres, of which

about 60,000 acres is above Peoria. From Beardstown to the mouth of Illinois River, a distance of about 90 miles, the overflowed valley is from two and one-half to four miles wide and practically all of this area has been leveed, leaving a floodway from 1,200 feet to 2,500 feet wide.

Between Beardstown and Peoria about 70 per cent of the overflowed area has been leveed. Between Peoria and LaSalle only one small district of 2,600 acres near Hennepin has been leveed. The areas of Illinois Valley reclaimed lands are as follows:

Grafton to Peoria	166,000 acres
Beardstown to Peoria	80,000 acres
Peoria to LaSalle	2,600 acres
Total reclaimed area	248,600 acres

This represents 60 per cent of the total area of overflowed lands in the Illinois Valley between LaSalle and the mouth of Illinois River.

The overflowed lands protected by these levees were all in a fine state of cultivation prior to the floods of 1922 and 1926. The levees have been repaired since those floods and most of this land is again in a good state of tilth.

Destructive Floods

Three or four levees were constructed along Illinois River before 1904 and most of the others were completed before 1922. There have been three destructive floods in the Illinois Valley since the levee-building era began, namely, in 1913 with about half of the present levees constructed a number of the levees failed; in 1922, about half of the levees failed; and in October, 1926, the greatest flood occurred and continued through the spring and early summer of 1927 breaking about half of the levees and flooding approximately half of all the reclaimed lands. The flooding of these districts checked the rise in the river which would have been about 1.7 feet higher at Beardstown if all levees had held.

Illinois River Levees Restored

All but one or two of the Illinois River levee districts, aided by State appropriations, have restored their levees since the 1926-1927 flood. The Mississippi River Commission, in charge of the flood control work on Mississippi River and up the tributaries as far as the backwater of the Mississippi extends, has taken over Illinois River from its mouth to Beardstown. The Mississippi River Commission, with appropriations from the Federal Government, is authorized to pay two-thirds of the cost of building and strengthening levees on the tributaries and has allotted $2,000,000 for the levees on Illinois River below Beardstown.

The Illinois Legislature in 1929 appropriated $1,000,000 for strengthening levees on Illinois River. Several districts below Beardstown are availing themselves of these appropriations to have their levees raised and strengthened. All flood control plans of the Mississippi River Commission are subjected to the approval of the Chief of Engineers of the U. S. War Department. The Commission plans for Illinois River levees conform substantially with the plans in the Illinois River Flood Control Report of 1929. This plan provides for setting levees back where the floodway is too narrow and for raising and enlarging the levees.

Effect of Illinois River Levees on Flood Heights

Flood control studies of Illinois River show estimated flood stages 9 feet higher at Beardstown and 3.0 feet higher at Peoria than the 1844 flood stage which was the highest known flood prior to the building of levees. In 1926 the observed flood stage at Beardstown was 3.86 feet above the 1844 flood. With all existing levees holding, the estimated flood stages will be 5.2 feet higher at Beardstown and 4.9 feet higher at Peoria than the record flood of 1926. At Beardstown a sea wall along the river front and levees back to the high land have been constructed by the State of Illinois.

The effect of the Mississippi River levees on flood stages has been similar and of greater magnitude than on Illinois River. Along the Mississippi several hundred miles of levees from 20 feet to 30 feet high are now required where the banks were overflowed only a few feet deep before any levees were built. Surveys show that the average depth and cross-section of the Mississippi River channel, and therefore its carrying capacity, below bank-full stage is substantially the same as before the levees were built.

The following illustration shows what would happen at Peoria if the river from Peoria to LaSalle, a length of about 60 miles and an average flood width of about 1½ miles, should be reduced to 1,500 feet between levees. The flood, beginning April 16, 1927, with river stage 19.2 feet at Peoria, crested at 24.65 feet on April 24th. The increase in storage computed from the stage heights and valley cross-sections and the total inflow is equal to the outflow at Peoria plus the increase in storage. Under present conditions, with only one levee enclosing about 2,600 acres of bottom land at Hennepin, the remaining overflowed area including river channel is about 58,000 acres. If the channel were reduced by levees or other means to a flood width of 1,500 feet including the river channel, the total area of water surface would be 13,700 acres or about 23½ per cent of the present flood area. The rise in the river

for the nine days from the 16th to the 24th of April, inclusive, was 5.45 feet. The total discharge at Peoria for that period was 778,000 acre-feet and the increase in storage was 315,000 acre-feet, or a total inflow of 1,093,000 acre-feet. The storage was 28.8 per cent of the total inflow, or 40½ per cent of the total outflow. During this rise in the river, the storage was almost half of the inflow on the day of maximum inflow and the maximum rise in the river for one day was 1.4 feet. The reduction in storage would have produced a rise at Peoria on the day of maximum inflow of 4 feet, instead of 1.4 feet. The river would have crested two days earlier and 3.75 feet higher at a stage of 28.4 feet. A stage of 28.4 feet would have overflowed all of the industrial area opposite Peoria and would have been about 3 feet deep in the Rock Island Depot at Fulton and Liberty streets.

There would have been a material increase in hydraulic slope from Peoria to LaSalle and the rise above would have been greater than at Peoria due to the combined effect of reducing the flood channel and the overflowed area.

Conclusions

The following conclusions are suggested:

1. That flood relief presents new problems as population increases, as agriculture and industry develop, and with the physical changes produced by natural forces and the works of man.

2. That engineering methods of flood control depend upon economic conditions and will be modified to meet economic changes.

3. That flood flows depend on precipitation, condition of the soil, topography of the watershed, and atmospheric temperature.

4. That diversion through the Chicago Sanitary and Ship Canal increases flood heights in the lower Illinois River from 0.5 foot to 1.5 feet.

5. That the construction of locks and dams for low-water navigation on the Illinois does not increase flood heights.

6. That economic conditions do not now justify development of detention reservoirs for flood control.

7. That storage reservoirs for municipal and industrial purposes are not now a factor in flood control in the Illinois Valley, but may be within two or three decades.

8. That the construction of levees along Illinois River has greatly increased flood heights requiring additional levees for areas naturally above overflow.

9. That the flood protection plans of the Illinois Division of Waterways and of the Mississippi River Commission, by setting back and strengthening the levees along Illinois River, will provide adequate flood protection for the 248,000 acres under levees so long as no new levees are built.

10. That higher levees or detention basins in the tributaries will be required to offset areas hereafter taken from the valley floodway.

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POLLUTION STUDIES OF ILLINOIS RIVER

BY

A. M. BUSWELL AND C. S. BORUFF

Illinois State Water Survey

INTRODUCTION

The State of Illinois has been conducting sanitary chemical and biological studies on Illinois River since 1874, or 26 years prior to the time Chicago started to divert her wastes into its waters. The earlier studies were conducted by the State Natural History Survey and were mainly biological in character. They were, however, supplemented from time to time by chemical studies. The State Water Survey, since its foundation, has been furnishing chemists and bacteriologists for these studies, and has been in full charge of the sanitary chemical and bacteriological studies since 1923. A number of papers and bulletins have been published on the general subject of the pollution of Illinois River. Such publications may be secured for a very nominal sum by consulting the publication indexes of the State Natural History Survey, the State Water Survey, and the U. S. Department of Public Health. These different studies, besides giving routine data as to the rivers' condition, have rendered to sanitary chemistry much fundamental information as to the pollution capacities of streams, their rates of biological oxidation, rates of reaeration, and the like.

The economic history and utility of Illinois River has already been dwelt upon by previous speakers and papers. One's attention should be called to the fact that any large body of water, such as Illinois River, is of vast economic importance as a natural resource which if properly used may safely dispose of a considerable volume of domestic and industrial wastes. The simplest and cheapest method of disposing of sewage is to empty it into some river or lake, and there to allow nature to take care of it without human aid. If, however, this body of water is over-taxed with this pollution load, then numerous other important economic factors come into play. Some of these factors have already been discussed by previous speakers and will be further discussed in forthcoming papers.

THE POLLUTION LOAD OF ILLINOIS RIVER

The pollution load of Illinois River proper, that is the wastes added directly to Illinois River, as well as the pollution load of the entire Illinois River drainage basin, is summarized in Table I. As the wastes

from the rural districts and from those cities located on tributaries, are largely stabilized by the time they reach the Illinois River proper, those cities which are located in the immediate vicinity of the river are the only ones responsible for the gross pollution of the stream. Table I shows that the total population equivalent of these cities amounts to more than seven million. The Illinois-DesPlaines River at Lockport, which has an average flow of only about 600 cubic feet per second, has, since 1900, received all the sewage and dilution water from the city of Chicago. The pollution load of the city of Chicago is equivalent to a population of 5,602,000 [3]. With the building of treatment plants and the recovery of by-product wastes by the industries, this load has been reduced about 26 per cent (Table I).

The only other cities along Illinois River that add appreciable volumes of wastes are Peoria and Pekin. Peoria furnishes 16 per cent of the total pollution load thrown upon the river, whereas Pekin furnishes only 3 per cent. It is gratifying to note that Peoria has realized its debt to society and has recently built, and is putting into operation this spring, a very modern plant for the treatment of its wastes.

TABLE I.

EQUIVALENT POPULATION OF ILLINOIS RIVER CITIES.*

Place.	Station (miles from Grafton).	Sewered population (1930)	Population equivalent of industrial wastes.	Total sewered population contributing
Chicago	292	3,880,000	1,722,000	†5,602,000
Joliet	288	41,753	26,000	67,753
Rockdale	285	‡1,477	.....	1,477
Morris	263	5,563	30,000	35,563
Marseilles	247	‡1,706	102,000	103,706
Ottawa	237	15,042	3,000	18,042
LaSalle	223	13,084	.....	13,084
Peru	222	9,121	1,000	10,121
Spring Valley	218	5,272	.....	5,272
Lacon	189	1,546	500	2,046
Peoria Heights	165	3,280	50,000	53,280
Peoria	162	104,788	1,000,000	1,104,788
Pekin	152	16,096	200,000	216,096
Havana	120	3,445	.....	3,445
Beardstown	88	6,353	.....	6,353
Total	.....	4,108,526	3,134,500	7,243,026

Population in drainage area, urban + rural	5,700,000
Population equivalent of industrial wastes	3,100,000
Total population equivalent of Illinois River drainage basin	8,800,000

* Revised Table I, State Water Survey Bulletin No. 28.

† Sewage treated by Chicago Sanitary District:

Partial treatment, population equivalent	2,153,000
Treatment, 100 per cent basis	1,473,000

‡ Population in 1920.

Parameters Used in River Studies

Of the various tests that are used in scientific studies of polluted streams and their self-purification, the following are the most important:

1. *Dissolved Oxygen.* The dissolved oxygen test accurately measures the amount of dissolved oxygen gas that is available in any given sample of water for oxidative reactions and for aquatic life.

2. *Biochemical Oxygen Demand.* This test measures the amount of oxygen needed to biologically stabilize any given sample of water or water-borne waste. It is usually expressed in terms of a 5-day demand.

3. *Bacteriological and Biological Counts.* These tests determine the total number and type of organisms found in any given volume of water. Knowing the characteristics and most common habitat of these organisms, the water may be classified accordingly.

The technique of making the above determinations is not so difficult, but factors relative to the manner of sampling, points of sampling, time of day, variations in pollution load, amount and type of dilution, rate of flow, temperature, biological flora found in the water being sampled, and the like, play such an important part in the actual data collected that only those experienced in such work should collect and, above all, interpret such data.

Pollution Zones

On the basis of data collected, and as an aid in the classification of these data, the writers [1, 2] have divided Illinois River into the following six sections or zones, each of which is briefly characterized:

1. *Zone of Recent Pollution.* That section of the Illinois-Des-Plaines River which extends from the point of confluence of the Des-Plaines River and the diluted wastes from the Chicago Drainage Canal down-stream to about Ottawa, has a very rapid and turbulent flow. As noted in Figure 1, which gives a profile view of the entire Illinois River, there is a fall of some 80 feet in this 50-mile stretch of the river. This upper river constitutes an ideal mechanism to insure maximum biochemical activity. There is relatively little sedimentation. The biochemical oxygen demand of the water in this zone is high, but, as noted in Figure 2, it is also removed very rapidly, due to the high degree of reaeration and active decomposition. The bacteriological counts are of a high order of magnitude (fig. 3) as are also the counts for colonial cileates, tubificid worms, and other forms of biological life common to heavy pollution. The dissolved oxygen of this very turbulent water is always low and in summer the stream is usually completely void of this all important gas.

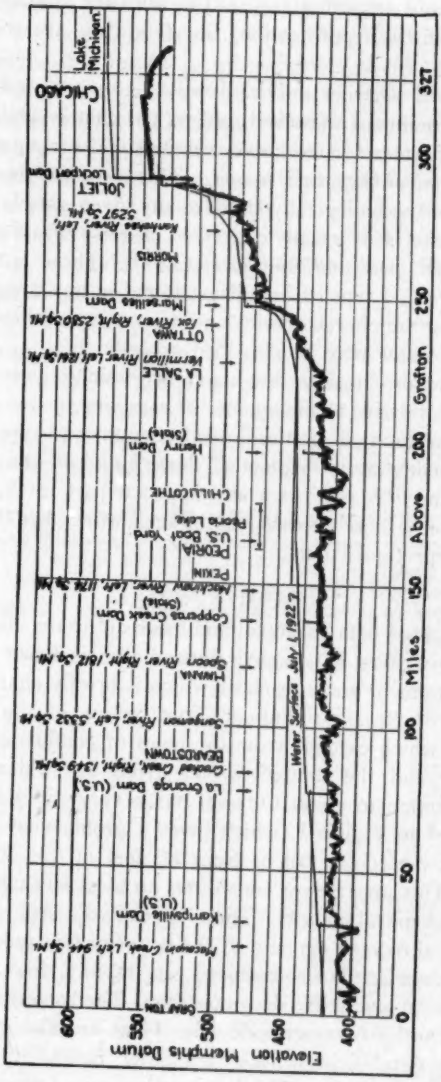

FIG. 1.—Profile of the Illinois River and the Chicago Drainage Canal

(By courtesy of U. S. Public Health Service)

2. *Septic Zone.* Due to the fact that the drop in elevation of the river between Ottawa and Henry is only about 10 feet in 50 miles (fig. 1) as compared with 80 feet in 50 miles in the "Zone of Recent Pollution," the rate of flow found in this second zone is sufficiently low so that much sedimentation takes place. This organic sediment lies practically dormant on the river bottom during the cooler months, but during the summer and fall biological action is accelerated by the increase in temperature to such an extent that an extremely high oxygen demand is thrown upon the river water that flows over this sludge bed. This demand for oxygen is so great that, in spite of reaeration, no free

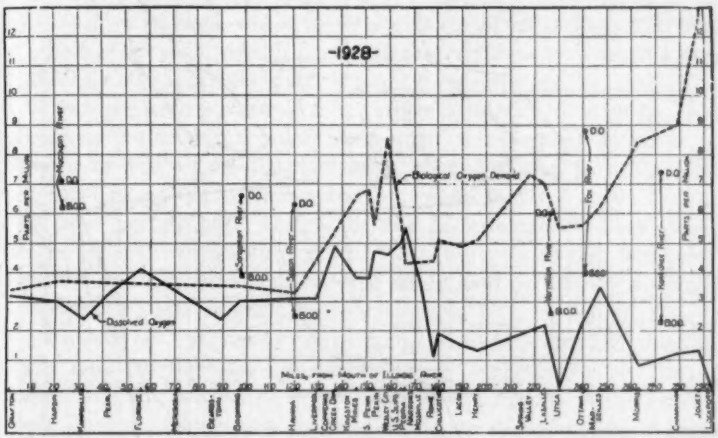

FIG. 2.—Summer averages of biochemical oxygen demand and dissolved oxygen data for 1928

oxygen is found present. Following the removal of all of this gas from the water, anaerobic decomposition sets in and the offensive odors common to this type of degradation are then liberated. It is a regretable fact that one of the State's most historic, most beautiful and most visited parks, namely Starved Rock Park, should be located on the banks of such a stream.

With the completion of the numerous dams that are now being built along the upper Illinois River in connection with the Great Lakes to Gulf Waterway System, there seems little doubt but what the flow between these dams will be sufficiently slow so that the organic matter, which now settles out on the river bottom between Ottawa and Chillicothe, will settle out between these dams which in summer will then virtually become large septic tanks. This septic condition could, of

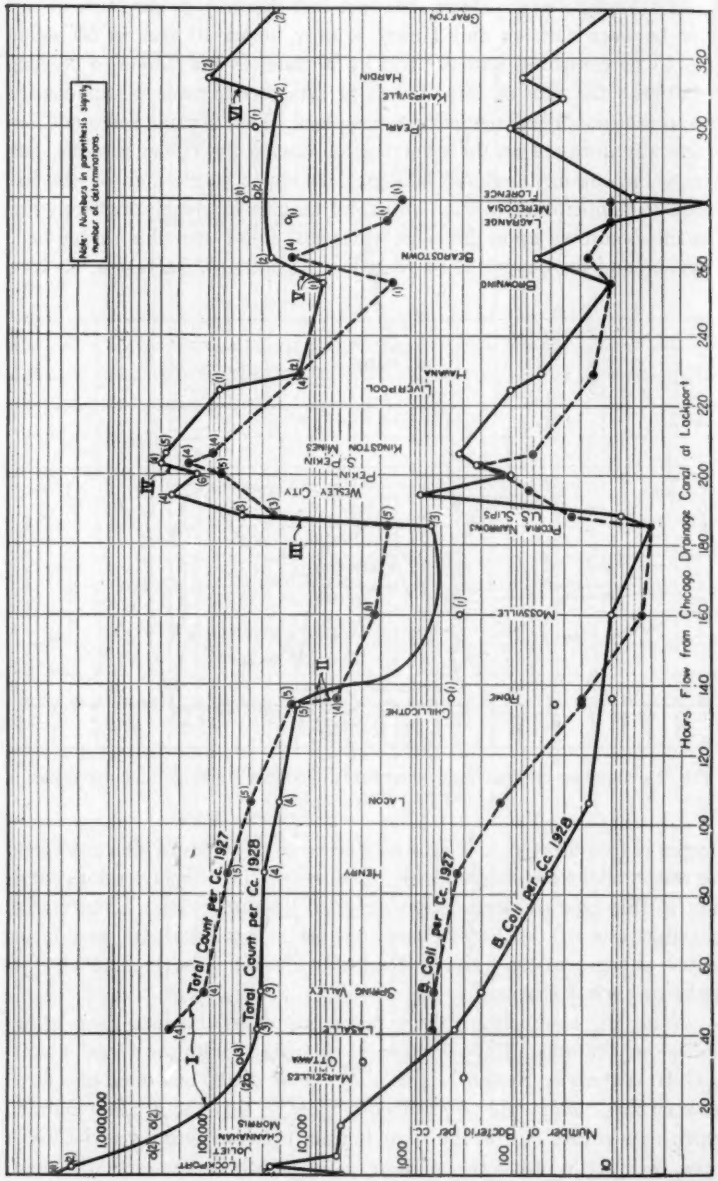

Fig. 3—Graph of bacteriological data for 1927 and 1928

course, be overcome by frequent dredging. With the advent of complete sewage treatment by the city of Chicago this problem would be eliminated.

3. *Polluted Zone.* That section of the river immediately following the septic zone is in many respects very much like its immediate predecessor. The river bottom carries a heavy blanket of sludge, but, as it is more nearly stabilized, the load on the stream is not as heavy. Chemical and bacteriological data bear out this fact.

4. *Zone of Marked Recovery.* That reach of the river between Chillicothe and Peoria is one of the most interesting of the entire river. The river widens in this section and forms the Upper, Middle, and Lower Peoria Lakes, which in all are about 18 miles long and from one-half to one mile wide. The average rate of flow in this reach ranges from 0.3 to 0.6 miles per hour, depending on the stage of water. This slow moving, wide expanse of water makes conditions ideal for the completion of the stabilization and purification of the wastes added to the river at its headwaters. Sedimentation, photosynthesis, reaeration, and the abundant growth of pure water organisms found in these lakes all play an important part. Chemically and bacteriologically (figs. 2 and 3) the river is sufficiently pure at Peoria Narrows so that with mere filtration and chlorination it could be safely used by the city of Peoria as its public water supply.

During hot summer seasons of low stage of water the pollution zones move further downstream, and if it were not for the Peoria Lakes, the Illinois River at Peoria, during such seasons, would be very foul. During the low water season of 1930, the anaerobic zone at times moved as far down stream as South Rome which is located four miles below the head waters of Upper Peoria Lake.

5. *Zone of Repollution.* The Illinois River no sooner gets rid of its one pollution load than it is again polluted. The cities of Peoria and Pekin are at present adding untreated domestic and industrial wastes equivalent to a population of about 1,400,000. The chemical and bacteriological data shown in figures 2 and 3 pictorialize the effect of these wastes. The flow of the river in this zone (Peoria to Kingston Mines) is such that no very definite sludge bed is formed in either this or the following reach of the river.

6. *Zone of Slow Recovery.* The river from Kingston Mines to its confluence with the Mississippi at Grafton has an average flow at medium stage of from 1.2 to 1.5 miles per hour. The soil in the lower Illinois River Valley is such that the river is turbid practically all the time. This turbidity inhibits the growth of algae which play such an important part in the reaeration of a stream. As a result of this, and

Fig. 3—Graph of bacteriological data for 1927 and 1928

other factors which need not be mentioned here, and the heavy load added by Peoria and Pekin, the lower river always possesses a moderate biochemical oxygen demand, a moderate bacteriological count, and only a fairly high dissolved oxygen content. This lower-most reach of the river with its odorless water, harbors but few tubificid worms and practically no colonial ciliates both of which are so abundant in the upper river. However, a variety of gill-breathing insect larvae and other forms common to slightly polluted and unpolluted waters are relatively abundant.

It has been the purpose of this paper to show in a general way how river studies are made and to point out the inter-dependency of the various physical, biological, and chemical factors involved in the self-purification of a polluted stream. With the complete treatment of Chicago's wastes and the wastes of Peoria, Illinois River should again become the stream described by scenic beauty admirers and sportsmen of the "nineties" as the most picturesque river and the best fishing and hunting grounds in the State. This may all be possible even though the river is called upon to take care of the treated effluent from the Chicago and Peoria waste treatment plants.

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ILLINOIS RIVER SANITATION

BY

SAMUEL A. GREELEY

Pearse, Greeley & Hansen, Chicago, Illinois

GENERAL STATEMENT

During the last decade or so there has been a growing public interest in river sanitation. An increasing knowledge of the latent hazards of pollution by bacteria of human origin has been a factor. The great development of transportation has increased the recreational use of rivers and thus called public attention to the disturbance of the natural condition of river waters by industrial and human pollution. Illinois River is no exception to the other great waterways of the United States and thus has been given much study and effort in the direction of improved sanitation.

THE ILLINOIS RIVER

Illinois River has a drainage area above the Mississippi of 28,344 square miles; and above Peoria of 13,479 square miles. Since 1903, it has received water by diversion from Lake Michigan at Chicago which has materially increased the low water rates of flow. Prior to this diversion, flows of 2,000 to 3,000 second-feet at Peoria are recorded. After the diversion, the dry-weather flow was seldom less than 6,000 to 7,000 second-feet and was more often upwards of 10,000 second-feet. As the ability of a river to receive and assimilate sewage depends in part upon the river flow, these changing characteristics are important. The Supreme Court of the United States has ruled that, after December 31, 1933, the annual average diversion be limited to 5,000 second-feet; and after December 31, 1938, to 1,500 second-feet, both in addition to the flow from domestic water supplies (or the sewage from the municipalities).

CHARACTERISTICS OF POLLUTION

Illinois River receives human and industrial sewage at its head waters from Chicago and from other centers of population on the drainage area. This pollution is decreasing at Chicago as treatment works go into operation and will increase in other cities as the population and industry increase, except as sewage treatment works are built. The natural condition of the river has been seriously disturbed by increas-

ing pollution during the last 10 to 20 years, with an expected marked improvement during the next few years as treatment works are completed at Chicago, Peoria, and probably elsewhere.

Two characteristics of river pollution should be noted. One is the general effect of pollution on the river as a whole, which takes into account the balance between pollution and the resources of the river and its tributaries. The other is the local effect of pollution adjacent to sewer outlets and below centers of population. Both characteristics require consideration.

River Pollution Investigations

From the view point of sanitation, the large rivers of the United States have been the subject of many important investigations. The United States Public Health Service have made extensive reports on the pollution of the Ohio, Illinois, and Mississippi rivers. In addition, Illinois River has been comprehensively studied by the Illinois State Water Survey and the Sanitary District of Chicago. The recent exhaustive studies of the upper Mississippi by the Metropolitan Drainage Commission of Minneapolis and St. Paul are of interest because of the similarity, in certain respects, with the Illinois. The sewage from the Twin Cities pollutes a stretch of the river extending some 60 miles to Lake Pepin, with conditions somewhat comparable on a broad scale to the pollution from Chicago in the 138 miles of river above Lake Peoria.

Economic Balances

Throughout these investigations some consideration has been given to the economics of river sanitation such as might be indicated by a comparison of the cost of sewage disposal works and the value of the resulting cleaner waterway. So far the cost of sewage disposal has not been regarded as prohibitive, but consideration has been given to a progressive installation over a term of years. The program worked out by the Metropolitan Drainage Commission for the Twin Cities calls for some 40 per cent complete sewage treatment by 1940 with the work gradually extended to complete treatment by about 1970.

Volume Balances

All the many engineering and bio-chemical aspects of river sanitation cannot be included in a brief statement. A rough picture is afforded by the relation between the river flow and population equivalent discharging sewage into the stream. With due reservation as to the influence of individual local river characteristics, the Engineering Board

of Review of the Chicago Sanitary District expressed the view that for each 1,000 of contributing population equivalent, there should be a flow of 6.0 second-feet for untreated sewage, 4.0 second-feet for clarified (settled) sewage and 1.0 second-feet for the effluent of trickling filters, aeration tanks, or similar treatment works. However, the Supreme Court allowed only 1,500 cubic feet per second which might figure about 0.26 second-feet per 1,000 population equivalent by the end of 1938.

Progress at Chicago

The present population equivalent of human and industrial sewage from the Sanitary District of Chicago has been estimated as approaching 5,500,000. The sewage treatment works now in operation are estimated to be treating the equivalent of more than 2,100,000 population or on a 100 per cent treatment basis, more than 1,473,000 people. When the program outlined in the decree of the Supreme Court is completed during the next seven or eight years, the Court expects evidently that the allowed diversion will care for residual and uncontrollable pollution, so that the river will start its journey through the state in a somewhat stable condition. The indications are that with the flow allowed, interest in sewage treatment projects will be increased markedly in other cities along Illinois River. .

Population and River Flows

Approximate estimates based on the Federal Census of 1930 indicate an urban population in the drainage area of Illinois River outside of the Chicago Sanitary District of about 1,000,000. In addition there is the sewage of industries which would increase this estimate to a very much higher population equivalent, perhaps in excess of 2,000,000. The indicated rates of dry weather flow in the river during the next decade (very likely less than 5,000 second-feet and as low as 3,500 second-feet at times at Peoria) do not appear to be sufficient to assimilate crude or untreated sewage, even for the river as a whole, while local considerations of immediate pollution point to the need for the installation of treatment works as at Peoria and at a number of cities on the major tributaries. No present statement can be made as to the extent and cost of additional sewage disposal works needed in the development and use of Illinois River. A start should be made in the larger cities by having these projects planned in a preliminary way so that public improvements built in the near future will not add unreasonably to the cost of sewage disposal works and so that financial programs can be arranged.

Summary of Factors in River Sanitation

The several important factors which influence the condition of Illinois River as regards sanitation may be summarized as follows:

a. The number of persons connected to the sewer system and discharging sewage into the river, and the volume of sewage.

b. The amount and character of industrial sewage, including its temperature, content of oil and sulphur, reaction, oxygen demand, and the like. Coarse suspended matter may lodge in sewers or strand along the river banks.

c. The rate of flow in the rivers, including the frequency and duration of floods and of protracted periods of low flow.

d. The thoroughness of mixing the sewages and river water with reference to a favorable use of the oxygen resources of the stream.

e. The physical properties of the river with seasonal variations including temperature, time of flow, ice conditions, conditions affecting reaeration and the like.

f. Biological conditions in the river water with reference to chlorophyl-bearing organisms, dead organisms absorbing oxygen, and the kind and number of plankton.

g. The uses to which the river water in its normal state is adapted.

h. The amount of sewage treatment upstream and the quantity of diversion from Lake Michigan.

i. The accuracy and extent of analytical data.

j. Financial considerations. As a matter of common law, no one has a right to injure a river water by pollution. This doctrine is often tempered by special situations. Sometimes, however, financial considerations are important if justly related to the population within the range of pollutional influence.

A FEW REMARKS ON CONSERVATION IN THE ILLINOIS RIVER VALLEY

BY

RALPH F. BRADFORD

Division of Forestry of the Illinois State Department of Conservation

NOTE: In planning the symposium on the economics of the Illinois River Valley, this subject was assigned to Director Ralph F. Bradford, of the State Department of Conservation, but due to his unavoidable absence it was handled extemporaneously by R. B. Miller, Chief Forester of the Department of Conservation, Division of Forestry.—EDITOR.

INTRODUCTION

Briefly, the property owned and operated by the State Department of Conservation may be classified under the head of fish hatcheries, game farms, fish and game refuges, and state forests. The total acreage devoted to these various purposes, according to the latest figures, amounts to 10,457 acres and possibly as much more is under lease as game refuges. Each class of property will be discussed briefly in order, with its purposes and outstanding features.

FISH HATCHERIES

The main state fish hatcheries are at Spring Grove, Mattoon, Rockford, and Carlyle, the first being the oldest and best developed, serving as a standard to work for. There seems to be a disposition on the part of the state not only to make these places function for the production of fish for restocking Illinois lakes and rivers, but also to develop them as places of interest to the community. With this end in view modern cottages for the care-takers are being erected at Mattoon, Rockford, and on the state forest and the grounds are being landscaped and made attractive, taking the fullest advantage of whatever natural beauty the site may already have. A neat brick pumping station has been built at Mattoon and the difficulty of keeping the hatchery ponds full, which has been giving some trouble, will be surmounted in time by the city of Mattoon by the construction of a new dam in the Little Wabash lower down than the present spillway. This will greatly increase the storage capacity of Paradise Lake, the public water supply, from which water has been pumped into the state ponds.

Game Farms

At the Yorkville Game Farm various species of pheasants are being raised [1], also quail on a tract of more than 700 acres near Mount Vernon and at the State Fair Grounds, Springfield, where forty acres are given over to the purpose and where another custodian's cottage will be erected. A trained game breeder who has worked under Coleman, of Virginia, with great success is now in charge of raising quail at the Fair Grounds and there is ample space for laying and rearing pens. The eggs are hatched in an electric incubator and the chicks are transferred to brooders which are entirely off the ground and each of which can be kept at a controlled temperature. The other method of quail encouragement applicable to farms in the corn belt is called the Stoddard method because he developed it in Georgia. It has been proved that the number of quail coveys on the average farm can be greatly increased by creating the proper environment for them in the way of food, shelter, and reduction of the number of their enemies. In this connection it may be said that the destruction of coverts along streams, roads, and ravines by fire and grazing as well as the disappearance of the Osage Orange hedge from the majority of the farms in the corn belt is largely responsible for the gradual decrease in the number of quail or bobwhite as a farm bird.

Fish and Game Refuges

The Horse Shoe Lake property of 3,160 acres situated 18 miles north of Cairo, in Alexander County, is a fish and game refuge and although the lake dried up the past summer (1930), it was a most opportune time to put in a dam which will hold the water to the proper level for ducks, geese, and fish as well as to perpetuate the cypress (Taxodium distichum) which is found there in its virgin condition along with plenty of tupelo gum swamps.

Dr. C. L. Stewart, of Urbana, in his paper on land utilization in the Illinois River Valley will no doubt mention the fact that many drainage districts are not able to pay land and drainage taxes and I would suggest that such land might be more profitably used for the production of timber, fish and game, and for another purpose which will pay good dividends, namely, recreation. According to some reports land for duck shooting purposes varies in price from $50 per acre in the lower Illinois River valley to $400 in the Beardstown area. The usual charge for looking after hunters is now $15 per day per man or $25 for two men. Sometimes ten guns are placed at a single hole or blind, which would mean $150 per day. This amounts to about $1 per duck and when we

add to this the amount the hunter spends at hotels, for gasoline and oil, care hire, ammunition, and other incidentals it may amount to as much as $2 per duck, which means quite a revenue for the farmer, for hotels and restaurants, filling stations, and a certain number of men employed during the season as pushers.

State Forests

The Union County State Forest located northwest of Anna and Jonesboro, now totals 3,319 acres and is suited for the production of timber, for watershed protection, for the preservation of wild life, and for recreation, since the law provides that state forests may also be declared game preserves. State forests can also be used for recreation the same as state parks, the National Forests of the United States having attracted more than 31,000,000 visitors in 1930. A full description of this property will be found in the "Illinois Farmer" of November 10, 1930, and in the April 1931 issue of the "Illinois Teacher."

Hunting Clubs

Contrary to the statement in the May issue of the National Geographic magazine by Wood [2] that "a law in Illinois forbids luring wild ducks with food," such legislation has never been passed, as a study of the state game law will reveal. The putting out of shelled corn in fields or in the Illinois River bottoms is commonly practiced, the method being to fill a boat full of shelled corn and anchor it to a tree in the evening. During the night the ducks sometimes come in in sufficient numbers to eat all of the corn in the boat, so that in the morning the boat floats in the water.

According to records in the office of the State Department of Conservation there were 440 hunting clubs licensed in the state in 1930, each club paying a ten dollar license fee. Our estimate is that 303 of these are located along the Illinois River or in contiguous territory, in about 19 counties extending from LaSalle to Madison County. Mason County leads with 89, Havana being a center for sportsmen; Cass is next with 38, Beardstown being a hunters' rendezvous; Marshall has 38 clubs, Putnam 29, Woodford 20 and Calhoun 18. Each gun club is required by law to keep an account of the number and species in the daily kill made by members and others at the club and to send this report in to the office of the Conservation Department, but such records are far from complete so that the total kill of ducks on the Illinois River can be only an estimate.

Effect of Low Water in 1930

Although for several summers prior to 1930 the high water in Illinois River had killed many trees, even the pecan, cottonwood, and willow, the summer of 1930 was characterized by very low water levels. According to one of your speakers there was only 20 inches of rainfall at Peoria, which is the lowest in 80 years. This has affected unfavorably the growth of trees over the state, actually killing a great many and slowing up the growth of those that remained alive. What was true of trees has also been true of the growth of fishes, if authorities can predict correctly. Adams [2] says, "It has long been known that by making a study of the scales of fish, it is possible not only to determine the exact age of the individual but also to learn something of the conditions under which it developed. If the rings, or annuli, are close together, with small spaces between them in a certain part of the scale we can infer that the conditions were not favorable to growth during the period when the part was added."

Several hunting clubs did not do any shooting at all in 1930 on account of the low water in Illinois, one man saying that it would have taken an increase of four and one-half feet of water to make the proper conditions at their club.

Commercial Fishing

The value of the commercial fishing in the Illinois River can be calculated better by others here present but if I am not mistaken, it was once estimated at well over $2,000,000 yearly. In addition to this there are pearl and mussel fisheries and the value of the pearl button blanks made from shells at several points on the Illinois River. Certain stretches of the river are closed to mussel fishing in order that the stock may have a chance to recover, which is in the interest of both the state and the mussel fishermen.

Conservation Measures

All the values I have mentioned could be greatly augmented by proper conservation measures, such as the prevention of stream pollution and closer observance of the fishing and hunting laws. Under the advice and help of the Sanitary Water Board, many of the cities along the Illinois, including the city of Chicago, are making efforts to treat their sewage so that in time only purified water will be returned to the stream. When that time comes, as we confidently believe it will, the Illinois will return to its own in the way of transportation, hunting,

fishing, and recreation, all matters of land utilization will have been worked out for the highest interest of land owners and the state, and there will be no need of a half day of discussion showing what is needed to be done but a full day to show what has been accomplished by the various agencies represented here today.

REFERENCES

[1] Wood, Junius B., Illinois Crossroads of the Continent, with illustrations from photographs by Clifton Adams, staff photographer, and a special map supplement of Illinois, The National Geographic Magazine, Vol. LIX, No. 5. May, 1931, pp. 523-594, Washington, D. C.

[2] Adams, L. A., Transactions of the Illinois State Academy of Science, Vol. 23, No. 3, March, 1931.

THE FISHING INDUSTRY OF ILLINOIS RIVER

BY

DAVID H. THOMPSON

State Natural History Survey

Perhaps most of you have heard it remarked that Illinois River is one of the most productive bodies of fresh water in the world. This great productivity is due to the high fertility of the soils in the Illinois drainage basin and to wide areas of bottomland lakes connecting with the river which permit this fertility derived from the soils to be utilized efficiently in the production of fish. A natural chain of biological reactions from the fertile elements of the water to fish takes place. In these basins there is time for the channel water to be transformed into microscopic life, or plankton, which is fed upon by worms, snails, insect larvae, and crustaceans, which in turn are used as food for fishes. The great productivity of the connecting bottomland waters of the Illinois Valley is analagous to the high productivity of the overflow lands of the Nile Valley and is explicable in the same terms—their fertility is periodically renewed from the river itself. In 1908, Illinois River produced 60 per cent of the total fisheries products of the entire state. At that time all of the waters of the state were open to commercial fishing and included fishes taken from the boundary waters of the Mississippi, the Ohio, the Wabash, and the Illinois portion of Lake Michigan; as well as from the Rock, Fox, Sangamon, and Kaskaskia rivers and other lesser streams so numerous within the state.

It may be appropriate at this time to scan the trend of the yield of commercial fishes from Illinois River. At various times from 1896 up until 1922 the Illinois Fishermen's Association, the Illinois Fish Commission, and the U. S. Bureau of Fisheries have taken censuses of the yield of commercial fishes. Beginning in 1896 the yield was 7 million pounds; in 1897, 10 million pounds; in 1899 and 1900 it was 11½ million pounds; in 1907, 15 million pounds; in 1908 two different sets of statistics gave 19 million pounds and 24 million pounds; in 1921, when fishing conditions were poor, 4 million pounds; and in 1922, when conditions were much above normal, 10½ million pounds. Estimates made during 1930 would seem to indicate that the yield has remained near the high figure of 1922. The sharp decline in yield from the peak of 1908 to 1921 and 1922 is due primarily to two causes—

pollution and the appropriation of wide areas of the middle and lower Illinois Valley for agricultural purposes. Following the completion of the Chicago Sanitary Canal in 1900, increasing amounts of organic wastes from the Chicago area seemed to be reflected by increases in the fish yields, but by 1910 and 1912 the amount of these wastes reached a point where the amount of oxygen in the water was depleted and the fishes as far downstream as LaSalle were wiped out. Further increases in the volume of wastes during succeeding years completed the destruction of the commercial fishery in the channel waters down as far as Chillicothe. Whether or not fishes were able to live in the connecting bottomland lakes of that section depended upon whether or not its lakes received channel water at ordinary water levels. Striking reductions were noted in Peoria Lake and in the channel as far southward as Havana. The peak of pollution was reached between 1916 and 1920. Since that time, partly because of reduction in the load of organic matter contributed to the river due to a slackening of wartime industry and to its treatment in sewage disposal plants; and partly because of prolonged periods of high water in which the sewage is so diluted that it is less harmful, such extreme effects of pollution on the fish yield have not been repeated.

Any discussion of the fisheries yield from the Illinois cannot be complete without mentioning the European carp and its place in the Illinois River fishery. The carp first made its appearance in Illinois River about 1885 from a stock brought from Europe and it first became an important item in the fishing industry soon after 1890. By 1898 the Illinois Fishermen's Association reported that the catch of carp exceeded in value that of all other commercial fishes and in 1908 it constituted 64 per cent of the catch, or 15,400,000 pounds. Data gathered by the Natural History Survey in recent years indicate that carp make up about 90 per cent of the entire catch of commercial fishes. The phenomenal success of carp in the Illinois River results from two outstanding facts. The Illinois River and its connecting bottomland lakes provide a habitat better adapted for the growth and multiplication of carp than did its ancestral home in Asia and in Europe. The carp is a close relative of the goldfish and like the goldfish is versatile and hardy. As the Illinois River became heavily polluted it was found that the carp could tolerate these unfavorable conditions with greater success than any of our native fishes. During a few years before and after 1920 when Peoria Lake was quite foul the carp was left in almost complete control.

In 1923 I noticed that many of the carp in the fishermen's catch showed abnormally formed heads. More complete studies made in 1926

and 1927 showed that this abnormality was closely akin to what we know as rickets in man and other higher, warm blooded animals. At that time it was found that 50 to 90 per cent of all the carp between LaSalle and Pekin showed this abnormality. When the rate of growth of these abnormal carp was compared with the rate of growth of normal carp found farther downstream it was found that the latter grew at a rate about twice that of the rachitic carp. Further studies seemed to indicate that the stunted condition of carp in the upper and middle river was due to the destruction of the green algae by pollution, and to substitution in its stead of blue-green algae and protozoa which cannot provide young carp with as complete a diet as does the green algae.

Estimates of the yield of fishes made about 1910 by the Natural History Survey showed that many of these bottomland lakes have annual yields as high as 150 to 300 pounds per acre. These yields are as high as those obtained from fish ponds under good cultivation in Germany. I might mention here that the area of the river channel between LaSalle and Grafton at the gage 10 feet Beardstown, which is about an average stage of water since 1910, is 45 square miles. The area of connecting bottomland lakes at this same stage of water is 201 square miles.

Formerly all fishes were fair game for the commercial fishermen and could be marketed at all times. Within recent years the State has regulated commercial fishing on the Illinois River by closed seasons, by prohibiting the sale of bass, crappies, and sunfishes at any time, and by placing minimum length limits on carp, buffalo, and catfish which make up 99 per cent of the commercial catch. In the beginning of the fishing industry on Illinois River the catch was sold locally in summer with shipments to the larger cities of the middle west in winter. Following that time ice came into general use and fishes were shipped as far as the eastern seaboard at all seasons. Still more recently live-cars have come into wide use for the shipment of live carp and buffalo to the New York and Philadelphia markets.

In recent years there has been a great deal of complaint about the table qualities of the fishes handled commercially from Illinois River. This disagreeable quality has been described as a taste or smell resembling carbolic acid, kerosene, or coal tar, and is commonly referred to by fishermen as the "gassy" taste. It seems quite certain that this "gassy" taste is caused by decomposition products of sludge and sewage absorbed by the flesh of the fish. During the past winter the price of Illinois River fish has been unusually low, largely because of the difficulties in selling "gassy" fish. The "gassy" taste seems to affect carp, buffalo, catfish, and sheepshead, all common commercial fishes. The commercial fishermen at a number of places between Peoria and Meredosia get rid of

some of this "gassy" taste by holding their fish in ponds of fresh water with clean bottom for a few weeks or months before they are sold.

The past fifteen years have been depressing ones to the commercial fishermen of Illinois River. They have seen the fishing industry wiped out of large areas of the upper and middle Illinois River by pollution from the Chicago area and to a lesser degree from Peoria and Pekin. The carp which makes up 90 per cent of the catch in the middle Illinois River has been stunted until it grows at only one-half the normal rate. Throughout the length of the river all kinds of commercial fishes have been rendered unpalatable by flavors absorbed from sludge and products of the decomposition of sewage. During this same period many of these highly productive bottomland lakes have been levied and emptied of their water and converted to agricultural uses. The outlook was indeed gloomy, but I think there are several reasons to expect the fishing industry of the Illinois to come back. The Chicago area, and Peoria as well, is committed to a program of sewage disposal plant construction which will lessen the load of organic matter thrown on the river. It seems likely that the amount of Lake Michigan diversion will be reduced so that there will be more time for the natural purification to take place before it reaches the productive fishing waters. Also the completion of the deep waterway will involve the construction of several dams between Lockport and Utica which will impound large volumes of water, and these will act as huge settling basins to diminish further the hazard of pollution to the Illinois River fishery. There is also some indication that many of the drainage districts of the Illinois Valley are proving unprofitable and will be abandoned as agricultural projects and will again be productive of fishes.